THE JOURNAL

OF

"The Royal Aeronautical Society"

with which is incorporated "The Institution of Aeronautical Engineers"

Edited for the Council by Captain J. LAURENCE PRITCHARD, Hon. Fellow

No. 215. NOVEMBER, 1928. Vol. XXXII.

NOTICES

Donation

The Council desire to acknowledge gratefully the donation of £250 by the Society of British Aircraft Constructors. This is the fourth year in succession that the Society of British Aircraft Constructors has made this generous donation.

Acknowledgment is also made of the gift of Journals from Mr. F. W. Hills.

Council Meeting

A meeting of Council was held on Tuesday, 16th October. Among the business transacted was the appointments of delegates to the International Civil Aeronautics Conference; the approval of the application for the formation of an Oxford Branch; other Branch matters; the receipt of a letter of resignation from the Honorary Solicitor, Mr. B. Woodward, and the appointment of Mr. L. A. Wingfield to the post; the nomination of Mr. Griffith Brewer to represent the Society on the Daniel Guggenheim Medal Fund; the International Aircraft Exhibition at Olympia being arranged under the auspices of the Society of British Aircraft Constructors to take place from 16 to 27 July, 1929.

International Civil Aeronautics Conference, Washington

The following delegates have been invited to represent the Society at the International Civil Aeronautics Conference to be held at Washington on December 12, 13 and 14:—

Air Vice-Marshal Sir W. Sefton Brancker, K.C.B., A.F.C., F.R.Ae.S., Past President of the Royal Aeronautical Society.

Captain R. J. Goodman Crouch, O.B.E., F.R.Ae.S., M.I.Ae.E.

Wing Commander E. W. Stedman, O.B.E., F.R.Ae.S., Chief Aeronautical Engineer in the Department of National Defence, Canada; and

Hon. Edward P. Warner, F.R.Ae.S., Assistant Secretary of the Navy for Aeronautics, Washington, D.C.

Election of Members

The following elections took place during October, 1928:—

Fellow.—William Scott Farren.

Member.—William Scott Farren.

Associate Fellows.—Francis Rodwell Banks, Harold Roxbee Cox, Lord Edward Grosvenor, Ernest Jones, Mostafa Riad Moursi, Whyrill Edward Park, William Stanhope Rope, George Clifford Dowsett Russell, Raymond Harold Sandifer, Hubert Sutton.

Associate Member.—Stanley John Stocks.
Associates.—Thomas Courtney Head, Charles Stuart Humphreys.
Students.—Haic Hraut Apcar, Brian Clifford Blasdale, Roger Francis Bulstrode, William Harold Coates, John Clarke, Walter Francis Dowsett, Vernon Alfred Robert French, George Victor Gibbins, Lynton Hallett, Garlies Mitchell Spinks, Paul Garton Stanley.
Companions.—Wentworth Randolph Chetwynd, Sir Robert McClean, Maurice Frederick Perry, Don Manuel de la Sierra, Edward Arthur Skinner.

R.38 Memorial Prize

Members are reminded that the R.38 Memorial Prize entries must be received by December 31st. The closing date for papers is March 31st. The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

Resignation of Mr. Woodward

The Council received with much regret the resignation owing to ill-health of Mr. B. Woodward, who has been Honorary Solicitor since October, 1912. Mr. Woodward drew up in 1912 the Regulations and Articles of Association of Aerial Science, Limited, the private limited company which controls the finances of the R.Ae.S.I., and the sound foundation which he then laid has been of enormous benefit to the Society. The Council have had recourse to his advice on all occasions when drawing up new rules for the Society, drafting regulations for various activities, and in the multitudinous cases where legal knowledge smooths the administration's path. The Council wish to place on record their deep appreciation of his services which have been so freely and readily placed at the disposal of the Society whenever they have been required.

Honorary Solicitor

Mr. L. A. Wingfield was appointed Honorary Solicitor on October 16th, 1928. Mr. Wingfield acted as Honorary Solicitor to the Institution of Aeronautical Engineers, and his advice and service were of great value during the negotiations for the amalgamation, and during the drawing up of the rules which came into force on January 1st, 1928.

Daniel Guggenheim Medal Fund

Mr. Griffith Brewer was nominated to represent the R.Ae.S.I. on the Daniel Guggenheim Medal Fund.

International Aircraft Exhibition, Olympia

The Society of British Aircraft Constructors have fixed the date of the International Aircraft Exhibition at Olympia for 16—27 July, 1929.

The First English Aeronaut

On Thursday, October 25th, the Bishop of Oxford unveiled a tablet in the church of St. Peter-in-the-East, Oxford, in memory of James Sadler, the first English aeronaut, who is buried in the churchyard. Sadler was born in 1753 and made his first balloon ascent at Oxford on October 4th, 1784. The gravestone of James Sadler was recently restored by the Society.

Among those present at the unveiling were Mr. Harold Sadler, the aeronaut's great-grandson; Sir Michael Sadler, Master of University College; the Rev. G. B. Crawshaw, the Principal of St. Edmund Hall; Dr. R. T. Gunther, of the Old Ashmolean; Wing Commander A. G. R. Garrod, representing the Royal Air Force; Mr. Griffith Brewer, representing the Royal Aero Club; Mme. de Landon, representing the Air League of the British Empire; Mr. J. E. Hodgson and Mr. J. Laurence Pritchard, representing the Royal Aeronautical Society.

Mr. Hodgson, to whose initiative and energies the memorial tablet is due, formally handed the tablet over to the vicar and churchwardens after the memorial service.

Physical and Optical Society

The Nineteenth Annual Exhibition of Electrical, Optical and other Physical Apparatus is to be held by the Physical and Optical Society on January 8th, 9th and 10th, 1929, at the Imperial College of Science and Technology, South Kensington.

The Exhibition Committee invites offers from research laboratories and institutions and from individual research workers of exhibits suitable for inclusion in the Research and Experimental Section. The exhibits in this section will be arranged in three groups:—

(*a*) Exhibits illustrating the results of recent physical research.
(*b*) Lecture experiments in physics.
(*c*) Historical exhibits in physics.

No charge will be made for space or catalogue entries of these exhibits and the facilities of the Imperial College will be at the disposal of the exhibitors. Offers of exhibits for inclusion should be communicated immediately, and in any case not later than November 14th, to the Secretary, Physical and Optical Societies, 1, Lowther Gardens, Exhibition Road, London, S.W.7.

Library

The following have been received and placed in the Library:—

The Law in Relation to Aircraft. L. A. Wingfield and R. B. Sparkes.
Guests of the Unspeakable. T. W. White.
The A.B.C. of Flying. W. Lockwood Marsh.
University of Toronto Bulletins, Nos. 2, 3, 4 and 7. Faculty of Applied Science.
Annual Report of the Director of the Meteorological Office, 1928.
Meteorological Office. Professional Notes—
No. 49. Sunspots and the Distribution of Pressure over Western Europe. C. E. P. Brooks.
Memoirs of the R. Meteorological Society—
Vol. III., No. 22. The Modification of the Strophic Balance for Changing Pressure Distribution. D. Brunt and C. K. M. Douglas.
Oxford Forestry Memoirs, No. 9. Aerial Survey in Relation to the Economic Development of New Countries. R. Bourne.
Laboratorio di Aeronautica della R. Scuola di Ingegneria di Torino—
"Prove su proietti a velocita balistiche inferiori a quella del suono." F. Burzio.
"La resistenza dell'Aria per corpi sferici a media e grandissima velocita." C. Pasqualini.
"La piastra piana e la legge di Kutta-Joukowski." C. Ferrari.
World Engineering Congress, Tokyo, October-November, 1929, Second Announcement. Kogakkai.
Abstracts from the Bulletin of the Institute of Physical and Chemical Research of Tokyo, Vol. I., No. 9.

The History and Development of Anti-Detonating Agents for Motor Fuel. H. S. Tegner.

Proceedings of the Institution of Automobile Engineers, Vol. XXII., Session 1927-28.

Transactions of the Institution of Naval Architects, 1928.

Industrial Arts Index, September, 1928. H. W. Wilson Co.

Practical Flying. B. Q. Jones.

Pseudo-Security. J. M. Spaight.

Aeronautical Research Committee Reports and Memoranda—

No. 1148. The Behaviour of a Single Crystal of Iron subjected to Alternating Torsional Stresses. H. Gough.

No. 1150. Reports and Memoranda of the Aeronautical Research Committee published between 1st March, 1927, and 30th June, 1928.

No. 1162. A Summary of the Experimental and Theoretical Investigations of the Characteristics of an Autogyro. H. Glauert and C. N. H. Lock.

No. 1153. Experiments with the Family of Airscrews in Free Air at Zero Advance. H. C. H. Townend, W. S. Walker and J. H. Warsap.

No. 1161. Report on the Drop of Stress at Yield in Armco Iron. A. Robertson and A. J. Newport.

No. 1164. Note on the Forces Experienced by Ellipsoidal Bodies Placed Unsymmetrically in a Converging or Diverging Stream. H. Lamb.

N.A.C.A. Technical Note—

No. 289. Preliminary Biplane Tests in the Variable Density Wind Tunnel. J. M. Shoemaker.

No. 290. Welding of High Chromium Steels. W. B. Miller.

No. 291. Gluing Practice at Aircraft Manufacturing Plants and Repair Stations. T. R. Truax.

No. 292. The Drag of a J-5 Radial Air-Cooled Engine. F. E. Weick.

No. 293. The Formation of Ice Upon Exposed Parts of an Airplane in Flight. T. Carroll and Wm. H. McAvoy.

N.A.C.A. Report—

No. 285. A Study of Wing Flutter. A. F. Zahm and R. M. Bear.

No. 288. Pressure Distribution over a Rectangular Monoplane Wing Model up to 90 per cent. Angle of Attack. M. Knight and O. Loeser, jun.

N.A.C.A. Bibliography of Aeronautics, 1925.

N.A.C.A. Thirteenth Annual Report, 1927.

Aeronautical Research Institute, Tokyo—

Report No. 39. Uber die Herstellung und die Mechanischen Eigenschaften des Duralumins. M. Goto, S. Fukuta, S. Horiguchi and T. Nagai.

No. 40. On the Inverse Wiedemann Effect and its Allied Phenomena. T. Kobayasi, H. Okumura and K. Simamura.

No. 41. On the Effect of Temperature Changes upon an Altimeter. T. Sasaki.

Scientific Papers of the Institute of Physical and Chemical Research of Tokyo—

No. 156. Effect of a Circular Hole on the Stress Distribution of a Beam under Uniform Bending Moment. Z. Tuzi.

No. 157. (In German.) S. Fujise.

Department of Scientific and Industrial Research, Engineering Research, Special Report No. 10. Researches on Springs, 4—The Surging of Engine Valve Springs. A. Swan and L. G. Savage.

Smithsonian Miscellaneous Collections, Vol. 81, No. 5. The Relations between the Smithsonian Institution and the Wright Brothers. C. G. Abbot.

Lantern Slides

The slides in the following list have been received and the Council desire to thank the firms for presenting them to the Loan Collection:—

The Bristol Aeroplane Company, Ltd.—

3418	"Bristol"	Jupiter	Series	VI.	engine.	
3420	,,	,,	,,	VI.	,,	
3421	,,	,,	,,	VI.	,,	
3386	,,	,,	,,	VII.	,,	(supercharged).
3387	,,	,,	,,	VII.	,,	,,
3388	,,	,,	,,	VII.	,,	,,
3391	,,	,,	,,	VIII.	,,	(geared).
3392	,,	,,	,,	VIII.	,,	,,
3393	,,	,,	,,	VIII.	,,	,,

D. Napier and Son, Ltd. —
Series XI. Napier "Lion."
Napier racing engine.

Rolls-Royce, Ltd.—
No. 157A. } A side view and two end views of the complete Rolls-
No. 158A. } Royce "F" Aero Engine.
No. 159A. }
No. 161A. Complete Cylinder Block with loose Cylinder Liner.
No. 164A. Complete Carburettors, Induction Manifolds and Air Intakes.
No. 163A. Wheelcase and Pumps.
No. 162A. Crankshaft.
No. 165A. Spring Drive.
No. 166A. A Pair of Connecting Rods with a Piston and Gudgeon Pin.
No. 160A. A plan view of the Valve Rocker mechanism of one cylinder block.

Short Brothers (Rochester and Bedford), Ltd.—
"Calcutta" Flying Boat—H.243 (c).
H.242 (h).
H.251 (a).
"Singapore" Flying Boat—H.165 (b).
H.206 (a).
H.163 (e).
"Mussel" Seaplane—H.33 (b).
H.33 (e).
H.256 (c).

The Society now has a very large and representative collection of lantern slides from which members may borrow those they require on the usual condition of paying the postage both ways and making good any damage that may occur. The Secretary will be pleased to send a list on application.

The Month's Arrangements

Nov. 1st.—"Testing of Adhesives for Timber," by W. D. Douglas, F.R.Ae.S., and Miss C. B. Pettifor, B.Sc., at the Royal Society of Arts, 6.30 p.m.

Nov. 2nd.—"Steel Tubing Manufacture and Manipulation," by W. Hackett. Lecture before Yeovil Branch.

Nov. 2nd.—"Britain's Position in World Aviation," by Brig.-General P. R. C. Groves, R.A.F. (Ret.). Lecture before the Leeds Branch.

Nov. 7th.—"Armstrong-Siddeley Aero Engines," by Major F. M. Green, O.B.E., F.R.Ae.S. Lecture before Yeovil Branch.

Nov. 8th.—"Machinery Installation of R.101," by Wing Commander T. R. Cave-Browne-Cave, F.R.Ae.S., at the Royal Society of Arts, at 6.30 p.m. Joint meeting with the Institution of Automobile Engineers.

Nov. 14th.—" Screw Threads," by W. Harmer. Lecture before Yeovil Branch.

Nov. 15th.—" Aeroplane Engines in Flight," by R. J. Penn, at the Royal Society of Arts, at **7.45 p.m.** Joint meeting with the Institution of Automobile Engineers.

Nov. 21st.—" Steel Works," by A. J. Croft. Lecture before Yeovil Branch.

Nov. 22nd.—" Weight of Aircraft," by Major T. M. Barlow, F.R.Ae.S., at the Royal Society of Arts, at 6.30 p.m.

Nov. 27th.—" Some Practical Aspects of Flying Boat Developments," by Flight Lieutenant B. C. H. Cross, D.F.C., R.A.F. Lecture before the Leeds Branch.

Nov. 29th.—" Production Problems," by F. Sigrist, A.F.R.Ae.S., at the Royal Society of Arts, at 6.30 p.m.

Nov. 30th.—" Napier Aero Engines," by W. Lind-Jackson. Lecture before Yeovil Branch.

OBITUARY

Sir Horace Darwin

1851—1928

It is with great regret that the Council have to record the death of Sir Horace Darwin, at Cambridge, on September 22nd.

Sir Horace was born at Dover, Kent, on May 13th, 1851, and was the fifth son of Charles Darwin. He was educated at Cambridge and took his degree as a senior optime in the mathematical tripos of 1874. He joined Messrs. Easton and Anderson as an apprentice and there obtained that practical engineering knowledge which had much to do with his future career. At that time scientific instruments of precision were difficult to obtain and Horace Darwin joined Mr. Dew-Smith in business to construct such instruments. Out of the venture sprang the Cambridge Scientific Instrument Company, of which Sir Horace Darwin was the chairman and moving spirit for many years. A large number of instruments designed by the firm for special purposes were due to the inventive genius of Sir Horace Darwin himself.

In 1903 he was elected a Fellow of the Royal Society, and during the war was a member of the Advisory Committee on Aeronautics and chairman of the Air Inventions Committee. He was made a K.B.E. in 1918.

Sir Horace Darwin read the first Wilbur Wright Memorial Lecture before the Society. The title of the lecture was " Scientific Instruments, Their Design and Use in Aeronautics," and was printed in the Journal for July, 1913.

THE ROYAL AERONAUTICAL SOCIETY

AT THE

INTERNATIONAL AERONAUTICAL EXHIBITION

BERLIN, OCTOBER 7—21, 1928

The Royal Aeronautical Society was represented at the International Aeronautical Exhibition at Berlin by an historical exhibit of a notable character. The exhibit was arranged in the Historical and Scientific Section of the Exhibition, and was designed to illustrate, by means of a carefully chosen selection of rare books, engravings, drawings, manuscripts and photographs, the gradual evolution of the idea and the practice of flight in Great Britain from the earliest down to recent times. It is safe to say that from the British historical standpoint no more interesting and illustrative collection, arranged as far as possible in chronological order, has ever been publicly displayed in this country or abroad. Indeed, in view of a common misconception that the part played by Great Britain in the development of aeronautical science at large was, until quite recent years, of negligible extent, the exhibit served a corrective and useful service. There are few, for instance, who fully appreciate the fact that the foundations of the modern science of aerial navigation, both as to heavier and lighter-than-air, were truly laid by an Englishman, Sir George Cayley, over one hundred years ago. The Society are peculiarly fortunate in being able to include in their exhibit a selection from Cayley's own papers, which were lent by the courtesy of Sir Kenelm Cayley, the present owner. These papers included a note-book used by Cayley between 1800 and 1810, which may with reason be claimed as the most important aeronautical manuscript of the 19th century known to be extant. It contains records of his experiment with a primitive form of whirling-arm—vastly different in structure from the immense electrically-driven apparatus at the National Physical Laboratory, though designed for an essentially similar purpose—on the results of which, taken in conjunction with other experiments with small screw propellers and gliders, he based his reasoned conviction that flight was a mechanical problem capable of assured solution. In other words, he was the first to lay down "that the inclined plane, with a horizontal propelling apparatus, is the true principle of aerial navigation by mechanical means." And because he realised that engine power was "the *sine qua non* of the case," he spent a great part of his life in trying to develop some type of caloric or explosion engine applicable to the purpose. The note-book also contains a description, with drawings, of a "tension wheel," specifically invented by Cayley for use with mechanical flying machines—a type of wheel which actually proved to be almost indispensable on the invention of the aeroplane, and which in its vastly wider application to the bicycle has become of world-wide utility. Other manuscripts in Cayley's own hand deal with such questions as the possibility of using bi-plane or tri-plane wing surfaces, and the great importance of reducing resistance by "ovalling" the section of supports or struts, and even the cords which he proposed to use for "diagonal bracing." Cayley's work is further remarkable in that throughout a period of over 40 years he combined practical experiments with theoretical reasoning. That towards the end of his life his ideas had projected themselves, so to speak, half a century ahead, may be seen in the draft reply of a letter to W. S. Henson, the designer of the first power-

propelled monoplane, in which Cayley—warning Henson that progress must inevitably be slow—points out with tragic foresight that "a hundred necks have to be broken before all the sources of accident can be ascertained and guarded against."

In the direction of airships—navigable balloons as he termed them—Cayley was equally ahead of his time, and as early as 1817, and again in 1841—the papers exhibited include a draft speech of the latter period—he urged the formation of an Aerostatic Institution, because he believed that the principle of "balloon floatage" would be practicable before mechanical flight, and because he knew that few if any individuals could undertake the great cost of carrying out experiments. For he fully realised the main principle on which airship theory rests, and was convinced that airships would have to be built on a very large scale. Hence his suggestion for dividing the gas container into several compartments, and hence also his suggestion that the form of the navigable balloon which he described—an elongated spheroid of 300 feet in length—would have to be maintained by "light poles and internal cross bracings of wire." In this connection it can only be added that Cayley regarded the airship as likely to afford "greater facilities for transporting men and goods through the air than mechanical means alone," and he gave expression to the belief that they would ultimately be used for the longer voyages, with mechanical flying machines serving a complementary purpose for "less remote distances."

The Cayley papers attracted as much attention and interest as anything shown in the Exhibition, and the Council feel that they were very fortunate in being able to exhibit them, thanks to Sir Kenelm Cayley and Mr. J. E. Hodgson.

But if the Cayley papers are in their way the most interesting exhibit, they form but a very small part of the whole story. That story begins with the legend of King Bladud, the "British king who tried to fly," who is said to have ruled Britain in the fourth century B.C., and who—as told in the picturesque verse of the "Mirror for Magistrates"—was killed in London trying to achieve winged flight. In the scientific sense it begins in the 13th century with Roger Bacon, the first man of learning to write of "flying machines," and is continued in the 17th with the printed writings of the "Flying Bishop," John Wilkins, and the great mechanician, Robert Hooke, who is said to have "invented thirty several ways of flying" before he left Westminster School. A century later the "romance of flight" is exemplified in the first German translation of Dr. Johnson's "Rasselas"—a rare edition printed at Mainz, with the English text, in 1785.

From the period of the invention of the balloon in 1783 the material both in books and engravings becomes more profuse. The exhibit was especially remarkable in the latter respect, and comprised from fifty to a hundred rare engravings ranging from 1784 to about 1860. Notable amongst these were several fine coloured aquatints of the ascents of James Sadler, the first English aeronaut—he made his first ascent from Oxford in October, 1784—and more remarkable as an inventor than is generally known. Many of the books shown were of special interest as describing notable flights or as dealing for the first time with different aspects of the application of ballooning—for instance, Dr. Jeffries' narrative of the first Channel crossing in 1785, or Major Money's first treatise on military ballooning, 1803. Of particular interest in connection with this German exhibition were the prints and documents connected with the record voyage of Charles Green's famous "Vauxhall" balloon to Weilburg in Nassau, the latter including the original congratulatory address presented to Green and his two companions by the Magistrate and Town Council of Weilburg in 1836. The ballooning history of the last half of the 19th century was illustrated by the doings of Henry Coxwell—who in 1845 published the first English aeronautical magazine—and James Glaisher, who undertook several famous high

ascents with Coxwell for scientific purposes, and who was mainly instrumental in the foundation of the Royal Aeronautical Society in 1866. The Society's exhibition held at the Crystal Palace in 1868—a copy of the catalogue was exhibited—was the first aeronautical exhibition to be held in any country, and it was especially notable by reason of the presence of John Stringfellow, who was the first to construct and fly a small power-driven model aeroplane.

Of later interest in the field of aviation were such items as letters from Percy Pilcher—the first Englishman to be killed in experimenting with a glider—in one of which, dated as early as 1898, he tells of his intention to make an oil engine suitable for use in one of his "soaring machines," an intention which his death most unhappily prevented. A much longer life of aeronautical endeavour—one which has not yet been adequately appreciated by his countrymen—was fully illustrated in the four large note-books and letter-books of Lawrence Hargrave. Hargrave in early life went out to Australia and his countless experiments with model flying machines and box-kites—the latter his own invention—were carried out in the neighbourhood of Sydney between about 1884 and 1915. The exhibition of these note-books, which belong to the Society, was some offset against the fact that owing to the indifference of both the land of his birth and of adoption, his remarkable series of model flying machines were destined to find a home in the famous Deutsches Museum at Munich.

In all the Society's exhibit comprised between 300 and 400 separate items, and by means of photographs the story was brought down to early types of British aeroplanes and airships, and such great achievements in aerial navigation as the first aeroplane crossing of the Atlantic in June, 1919, and the complete double voyage from England to America of the airship R.34. The significance of the whole exhibit was vastly increased by the loan from the Air Ministry of the very remarkable and extensive collection of aeroplane models, some part of which were exhibited at Wembley and which were more recently on view in the Museum of the United Services Institution. Taken together, the two sections of the exhibit—the books, engravings and manuscripts which deal with history, and the models which tell of constructional achievement—may be held to demonstrate that, while admitting the comparative slowness of Great Britain to take up with adequate enthusiasm and energy the cause of aviation in the early years of the century, her contribution to the science and practice of aeronautics at large has been a very real and notable one.

The selection, preparation and arranging of the great amount of material which has been available, have been in the hands of Mr. J. E. Hodgson, the Honorary Librarian of the Society. Mr. J. E. Hodgson, who is, of course, well-known as one of the leading authorities on aviation history, not only devoted a very great deal of time and a vast amount of energy to make the exhibit representative and worthy of Great Britain, but he also lent the Society a large number of valuable books and prints from his own collection, and obtained permission, from the present representatives of the family, to include Sir George Cayley's aeronautical note-book and other important papers.

The Council were fortunate that its President, Colonel the Master of Sempill, was able to accept an invitation from the Committee of the Exhibition to give a lecture, as the British representative. A very great deal of the successful initial preparation and organisation of the exhibit was due to the unstinted efforts of the President on behalf of the Society, and the Council wish to express their acknowledgment and thanks to all those who laboured so willingly to make the exhibit the success it was. The Council acknowledge gratefully, too, the great help which was extended to the Society and its representatives by Mr. Karlowa, the representative of the Exhibition in England, who laboured indefatigably to make the whole British section a success, and Dr. Liebmann, under whose supervision the Historical Section was arranged.

PROCEEDINGS

FOURTH MEETING, SECOND HALF, 63RD SESSION

A Joint Meeting with the Institution of Automobile Engineers was held at the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Tuesday, February 7th, 1928, when Wing-Commander I. G. V. Fowler read his paper on "Repair of Aero Engines."

The Chair was taken by Major E. G. Beaumont (President of the Institution of Automobile Engineers), who was supported by Colonel the Master of Sempill (President of the Royal Aeronautical Society).

REPAIR OF AERO ENGINES

BY WING COMMANDER I. G. V. FOWLER.

1. Aero engines, whether in Service or Civil use, work under very different conditions from engines used in mechanical transport. It is absolutely necessary that a high standard of reliability should be constantly maintained, although long periods of full-throttle, or nearly full-throttle running militate against this, especially when it is considered that the weight of these engines has to be cut down in every possible manner.

2. The result is that, on an average, aero engines require complete overhaul about once in every 100 flying hours. This period is on the whole shorter in the engines repaired by Service personnel, and longer in engines repaired by the makers, due, I think, to the differing standards of skill.

3. When a considerable quantity of flying is being done, the flow of aero engines coming in for repair may reach very large figures. If intensive operations are long continued, the question of the repair of aero engines being used for attack or defence may easily become of vital importance.

4. Taking the long view, it would seem that in the distant future this grave disadvantage must be overcome by extending the period between overhauls very considerably, or better still, by producing an engine that will do 1,000 or more hours without requiring anything beyond top overhauls and the Squadron and minor adjustments in which case it might be worth while scrapping the engine after that time and not overhaul it at all. This is the ideal, and it is thought possible of attainment.

5. The author hopes that it will not be many years before this very high standard is attained; and the immediate and practical alternative seems to be the design of aero engines so that the repair could be expeditiously and accurately carried out by the Squadron personnel normally employed upon maintenance. This would be brought about by so designing the components that replacement would involve the very minimum of fitting, and preferably none at all. For example, present-day engines give a considerable amount of trouble with white-metal bearings, especially those employing large numbers per engine, and the author would suggest that all white-metal bearings should be replaced by ball or roller bearings, or some other substitute, and the sources of supply of these items, which in the last war proved a limiting factor, would have to be made considerably more broad-based than at present.

6. The steps being taken by the Service to this end are repair of aero engines as far as possible in Squadron instead of at depots, as a temporary measure, but it remains to designers to carry the above policy further towards its attainment.

7. It will be appreciated that the distribution of large quantities of engines and tools amongst a number of Squadrons does not produce the same output of overhauled engines as would be the case were they concentrated at a repair depot as under the present system. But this is a necessary step towards the improvement of the fitter personnel of Squadrons, which would otherwise be employed solely upon maintenance, and would never get experience in Squadrons of a complete overhaul. This would result, in course of time, in two different classes of fitter being produced for Service use; one who had been all his Service life accustomed only to maintenance and who could not carry out a complete overhaul, and the other having worked the whole time either in depots or in workshops who had no experience, except that gained on a test bench, of running faults. This situation presents great difficulties in the future in the exchange of personnel as between the various units of the Service, and steps must be taken to guard against this.

8. The Service policy at the moment, therefore, consists in the repair of the majority of aero engines in use either by repair depots or by contractors. A small proportion are even now repaired by Squadrons solely for instruction or the giving of experience to their mechanics. It must be realised, however, that the whole of the repair depots in the Service can deal with only a very small proportion of the aero-engine overhauls required by the whole of the Service; the output of the depots, and in particular the home depot, could be very greatly increased if these units worked under production conditions. Their policy must, however, in the first instance be the production not of overhauled engines but of skilled mechanics, whilst the present type of engine is in use.

9. Admittedly, steps towards the ideals set out above have already been taken by designers and manufacturers. As a matter of personal opinion, the present air-cooled radial engine is a very great advance upon any water-cooled engine in existence from the maintenance point of view. A very considerable additional complication exists with all water-cooled engines, although it is admitted that, up to the present, for very high speeds, they allow of better streamlining than the air-cooled radial and may have a higher thermal efficiency. In a Service in which maintenance is of such vital importance however, these difficulties will sooner or later have to be overcome; apart from this the reduction of white-metal bearings in the air-cooled radial engine and the elimination of cylinder water jackets immensely reduces the work to be carried out in an overhaul, either by a Squadron or a depot.

10. Given that for some time Service aero engines will continue to be overhauled in repair depots, the functions of such depots in general may be considered before passing on to the detailed overhaul of an engine.

11. The functions of depots in India and Iraq differ widely from those at home, or the repair depot in Egypt. All depots are intended to produce as large a proportion as possible of the overhauls required by the Command they serve. The cost of British labour in Iraq and India is so high that it pays to post to these depots only the most skilled men, in order that the output may be a maximum. It is not economical, therefore, in these depots, to carry out anything in the nature of experience instruction of Service ex-apprentices on anything but a very small scale, if at all.

12. Labour costs in the Egyptian depot, and especially in the home depot, are approximately only 50 per cent. of those in India and Iraq. The function of these two depots becomes, therefore, the production not alone of overhauled aero engines, but of experienced mechanics and, particularly, experienced N.C.O.'s

for the rest of the Service. At Henlow this work takes precedence over the output of overhauls, and this policy is reflected in parts of the organisation, and in particular operations, a matter which will be dealt with later.

13. Dealing first of all, therefore, with the use of the home depot for the production of ex-apprentices with good experience of overhaul work, it must be realised that practically every man in the home depot at present is in the position of an improver. A small proportion of the N.C.O.'s have experience which would rank with that of a craftsman in civil life, and these men correspond to the foremen. The general level of skill of hand of the majority of men in the workshops is, however, not as high as that which obtains in civil factories, where the proportion of improvers to really skilled men is probably no higher than 30 per cent.

14. The improver in the Service finds himself working alongside men little more skilled than himself, and a system of inspection far more detailed than that necessary in civilian factories is required to check the numerous errors which must thus occur. It will be realised that a very much greater output, as well as possibly more reliable and long-lived aero engines, could be obtained by modelling a Service repair depot upon a civilian workshop; that is, as far as possible, one man, one job, and a bonus for output. As stated, above the absolute necessity of the production of mechanics rather than the production of overhauled engines prevents any such re-organisation of Service workshops.

15. Before passing on the overhaul of engines, the author would like to point out that the home depot is particularly well fitted to carry out the instruction of ex-apprentices at the same time as the overhaul of engines. Amongst the facilities obtaining at Henlow, and in a lesser degree in the overseas depots, may be listed the following:—

> The Service mechanic, unlike the civilian mechanic (who is usually a specialist on one engine, and in many instances is a specialist on a certain component only), may be called upon at any time during his service to carry out maintenance or overhaul work on several types of engines. He has therefore to have a rather more general knowledge of these types than a specialist knowledge of one particular type, as is acquired by the civilian.
>
> The mechanics, as soon as they are placed in an engine shop, are put on some particular component, and usually remain on it for a period varying between two and four months. In some cases where the work is more complicated, the period is six months, after which they move on to another component, and finally move on to another type of engine. As ex-apprentices work on these production jobs, they are limited to times and to dimensions, and the fact that their work will be used gives them a sense of pride and responsibility in the work.
>
> As far as possible the very latest repair methods are employed. As a general principle every effort is made to adapt the jigs and tools used by the manufacturer in the production of the engine. It will, however, be realised that jigs and tools in use on new parts cannot always be adopted for use on worn parts. The depot workshop staff is continually designing, manufacturing and modifying jigs and hand-operated mechanical tools in addition to those supplied by the maker, which can be used not only by repair depots but also by Squadrons, in overhaul work and which would be of great value to a depot or Squadron carrying out overhaul work in a field of operations situated outside a reasonable working distance from a civilian factory or a Service depot equipped with heavy fixed machinery. Apart from this the author is of opinion that if Squadrons *even at home* are to undertake complete overhauls in the future, it will be essential for them to be equipped with such

hand-operated mechanical tools; he looks forward, in fact, to the day when engines have so far advanced in reliability and ease of maintenance that a depot such as Henlow will be used solely for the repair of new types of engine only in order that the experience gained may be used towards the design and test of these repair tools before issue to Squadrons and also for the instruction of N.C.O.'s in the repair of the new types of engines together with the application of the appropriate jigs and tools referred to above. We shall then be approaching the age of the " King Dick Engine."

The depot output is fixed at a low limit, for reasons previously stated, but an endeavour is made to produce overhauls equal in quality to those carried out by civilian contractors. For this reason, a close liaison with engine manufacturers is maintained. Engines overhauled at Henlow are occasionally sent to makers' works for test and report by the A.I.D. Officers and men often go to the works on visits or on courses, and contractors' personnel are occasionally attached to the depot workshops for periods of one month. As far as possible, therefore, the best methods of civilian contractors are imported into the Service.

A close liaison with Squadrons is also maintained. Engines and aircraft are allotted when overhauled straight to consuming units, and do not therefore remain for long periods in store. Squadrons are asked to give an early report, so that if any complaints are made action can be taken with the personnel responsible. Authority has been asked for exchanges of officer and airmen personnel between the depot and Squadrons for short periods; direct correspondence and visits have also been approved, and the depot is responsible for the direct supply to any Squadron of special tools, modification charts, drawings, etc.

Large numbers of labour-saving tools are sent to the depot for test and report, and the best of them are retained in use on production work. Similarly, labour-saving tools are sometimes designed and developed by depot personnel, and in time their use is extended to Squadron and overseas depots.

The author will now proceed to outline the procedure adopted in the repair of an engine by a R.A.F. depot. For the purpose of this paper he has chosen the " Liberty " engine, which has been in use for some years in the R.A.F., and the overhaul methods of which may be considered as stabilised.

The principles of overhaul observed throughout the engine are as follows:—

All parts which are broken, damaged in a way that the damage may be a source of danger, or worn beyond maximum limits of wear allowed, are renewed. Parts worn beyond the limit but which can be built up by metal deposition or re-installed as in the case of white-metal bearings, are repaired. This is done even where it might be economically unsound to do so in the case of a civilian manufacturer, since the principles governing the repair are:—

1. Training experience for the mechanic.
2. Availability of new spares in store.
3. Consideration of possible economy.

A feature is made of selective assembly where such a method would enable us to use a worn part with an oversize part. In the case of some engines, oversize parts are actually manufactured for the purpose.

Overhaul

The engine is received by rail, road or air into the depot and is handed over to the " engine pool," where it is checked over for external components; magnetos and sparking plugs are removed and dummy plugs fitted in their place. The engine is retained until required by the shop for overhaul. The officer in charge of the " engine pool " issues the engine to the officer in charge of the appropriate

repair shop, as and when requested to do so by that officer. The log book of the engine, which contains a record of the engine, both for flying and mechanical adjustments and modifications, is received by stores and handed over to the officer commanding engine repair section, who, after recording the receipt, forwards it to the officer in charge of the engine shops (together with a record of overhaul book), who extracts the more important information contained therein, and logs it in a special book kept for statistical purposes.

The engine then goes to the stripping bay, where every component is taken right down; valves are removed from cylinders, rings from pistons, camshafts, water pump, C.C. gear generator, and their respective drives, are dismantled. Crankshaft oil retainers are removed, rubber joints taken off and scrapped, carburettors, main bearings, generators, and connecting-rods complete are returned to main stores. These components are in turn sent by the stores to the machine shop for reconditioning, and in place of these, new or reconditioned components are drawn from the stores. All the components received as a result of stripping, with the exception of those returned to stores, go over to the cleaning bay, where steel parts are cleaned in a caustic soda and hot water bath; other parts which are affected by caustic soda, such as those of copper and phosphor-bronze, white-metal bearings, etc., are cleaned in paraffin and hot soapy water. This method of cleaning is not altogether satisfactory, as a large number of man-hours are thus expended on what is non-productive work. Experiments are being made to overcome this drawback, and to find a more suitable method of cleaning parts such as the use of steam and paraffin ejectors, and it is hoped that a considerable saving of time will be effected.

Operation No. 1—Carburettors

Strip carburettor completely. Inspect castings for broken parts and cracks. Examine for defective threads. Scrap unserviceable castings at once, to save waste of time in cleaning. Scrap all parts rendered obsolete by modifications, *i.e.*, aluminium throttle barrels, aluminium needle cages, and brass needles. These parts are replaced by phosphor-bronze barrels and cages and stainless steel needles.

All remaining parts are cleaned in paraffin and hot soapy water and checked for wear, parts not up to standard being scrapped. New parts are drawn from the main stores to replace unserviceable parts. Fit throttle barrel by scraping liner in top half casting, and taking markings. Clearance between barrel and liner:—Minimum 0.005in., maximum 0.010in. Fit throttle casing end plates and bushes. Face up bushes and lap end-plates until throttle can revolve freely but without end play. Remove barrel and *end-plates, and lap top and bottom half castings* together with Weston's water grinding paste. Soak castings in hot water to remove the paste. Fit altitude-control cock. Test for fit in housing with blue markings. If necessary, fit new cock with oversize outer barrel; copper deposit 0.012in. on external circumference and grind to fit housing. All holes in cock must register with the holes in the casting. Fit snug in cock and draw home on the taper. Fit grub-screw to altitude-cock nut in position. Scrape top face of top half casting and both faces of the adaptor. Fit adaptor to body with ballite washer between. Assemble throttle barrel in casing and fit end-plates. Fit throttle-arm and throttle-stop. Wire up end-plate screws with 17 S.W.G. copper wire. Fit dummy guard tubes and filter and diffuser caps to bottom half. Fit up with needle, needle seating and float. *Set up level on jig for testing petrol level. Test for flooding at 4lb. per sq. in.* If seating leaks, cut and lap with special tools, and polish with metal polish until seating is petrol-tight.

Set level to 8mm. below the lip of the guard tubes. Test with gauge cut in steps from 7mm. to 10mm. Raise or lower level of petrol in guard tubes by altering position of the collar on the needle. Remove dummy guard tubes and diffuser caps.

Calibrate jets on Brown and Barlow Flowmeter. Set main jets to 490 c.c., and pilot jets to 300 c.c. Assemble jets in diffusers, and fit diffusers into casting with fibre washers. Replace diffuser caps and washers. Modify needle cage. Recess one end of fulcrum-pin hole to $\frac{1}{8}$in. diameter by 1.5mm. Lock needle-seating with copper tab washer. Fit needle weights and fulcrum pins. Assemble top and bottom halves together with paper washer between them. Lock filter and diffuser caps with wire. Give final test for leaking caps at 4lb. per sq. in. Fit air-intake adaptor.

Inspection by N.C.O. and officer in charge of shop, and return to stores.

Operation No. 2—Ignition Units

Delco Heads

1. Stripped right down for examination and cleaning of insulation strips and bushes, as well as all mechanical fittings. All cleaning is done with petrol.

2. Examine contact points, springs, rubber buffers and fibre blocks of contact-breaker arms—three in number. Points are faced up where required, and then only if the rubber buffers and fibre block are serviceable; if either of these is unserviceable, the arm is scrapped, and these items are not easily replaced, owing to the method of constructing the contact-breaker arm assembly, namely, riveting together of components. The two ball bearings carry the high tension brush, and must have no play, since it is impossible to synchronise accurately the two main contact-breakers if bearings are worn. The cams, being hardened steel, lubricated by an oil pad, and working against fibre blocks of the contact breaker, do not wear.

3. A megger test is made on the condenser of the coils in the distributor cover, an insulation test of a minimum of 5 megohms is required of each of these units; the coils are also tested for continuity.

4. Pre-assembly. Adjustment of contact-points of both main contact-breakers is to be set at 0.012in., points of the auxiliary contact-breaker to be set to 0.015in. Synchronising of the main contact-breaker points is done by two lamps and battery, suitably connected for that purpose.

5. The heads are then fitted to camshafts of a dummy engine which is belt-driven from one of the line shafts in the shop, the high tension terminals are connected to spark gaps which are under observation, the remainder of the circuit is coupled up, as in service, to the generator, voltage regulator, and battery. A test is given of $\frac{1}{2}$ hour duration, at normal engine revolutions, namely, 1,600 revs. per minute, the brush and cams therefore running at 800 revs. per minute.

6. All clearances and gaps are checked over after mechanical test. Note:—Voltage regulators are not received for overhaul.

Delco Generators

1. Stripped right down, for removing both end castings of aluminium, thus allowing access to bearings, brush gears, armature, and field coils. All parts (except those carrying coils, etc.) are washed in petrol.

2. Brushes and their springs examined, all worn parts to be replaced. The ball bearing (which is really the only one in the generator) is to have no play whatever; it is situated in the brush end, or commutator end, the generator as installed in the engine being in the vertical position, the armature housing from the top ball bearings, which is a combined radial and thrust bearing, the lower bearing is a stuffing box, or gland packed with grease packing, which is cleared out and packed with fresh grease and packing if required. This lower bearing is a steady bearing, and does not support the shaft in any way.

3. Armature and field coils are megger tested for insulation leakage, to a minimum of 5 megohms, also tested for continuity.

4. Re-assemble.

5. The generator is then fitted to a dummy engine, belt-driven from a line shaft in the shop; corrections are then made to two Delco heads and battery if available (through voltage regulator), if heads are not available a suitable resistance is inserted in circuit with the battery to give a charge rate of 5 to 7 amps. at normal revs. per minute of engine crankshaft, namely, 1,600. The generator is geared 1½:1 of crankshaft, therefore generator revolutions were 2,400 per min. This test was given for half an hour. A slow-running check is made to ensure that the generator commences to charge, or cut in, 600 to 650 revs. per minute.

Operation No. 3—Gears and Drives

The generator driving shaft, lower driving shaft, crankshaft bevel, double bevel, and C.C. gear are drawn and viewed. The distance-pieces are checked for correct length, to ensure proper meshing of the gears. The ball bearings are checked for wear and tested for size and fit in the housing. The felt washers are viewed and the whole of the generator shaft is then assembled. The lower driving shafts are viewed similarly with special attention to condition of shaft and gears, length and condition of distance-pieces, condition of all ball bearings, housings, flanges and keys.

The crankshaft bevel is fitted to the shaft. This gear used to be fitted to the shaft in the main-bearing bay, but it was found more satisfactory to fit it in the gear bay so that the number of shims could be adjusted to suit the other gears. Double bevel drive is viewed and the gear fitted, care being taken to have the correct gear uppermost and the bearing the right way round. The housing is then bolted and pinned. When viewing the C.C. gear the cams are checked for wear and the casing examined—the ball bearings are examined and it is nearly always found that they are in a very worn-out condition, and have to be replaced. The C.C. gear is then re-assembled. The crankcase is received from the bearing bay and the gears are all fitted up and tested for correct mesh and backlash in the following order:—(*a*) Crankshaft bevel (adjusted by means of shims, and bolted up and pinned; (*b*) Double bevel—noting particularly that it is fitted the correct way up; (*c*) generator drive and lower driving shafts have to be fitted more or less together, and these are adjusted by shims.

The backlash of every gear in the engine is accurately tested by means of a simple device (consisting of six pieces). The crankcase is now ready to pass to the connecting rod bay. The crankcase and all the components are now passed to the erectors.

Operation No. 4—Crankshafts

The crankshaft, together with the propeller hub and shaft, is viewed and tested as follows:—

Crankpins and journals for size, ovality, and radii. Should the crankshaft require regrinding, it is sent back to the main stores with a form showing requirements, and a reconditioned or new shaft is drawn in its place.

The original shaft is then sent by the main stores to machine shop, where the necessary grinding operations are carried out.

We allow a crankshaft five regrinds of 0.005in. each, which are called:—Full size, 2.625in.; limit plus or minus, 0.001in. radii. A, 0.005in. small; B, 0.010in. small; C, 0.015in. small; D, 0.020in. small; E, 0.025in. small.

The machinist takes the smallest amount off the shaft that will enable it to clean up, but he grinds all pins to one size, and all journals one size. That is to say, should No. 1 crankpin require grinding to size B, and the remainder to size A, the whole shaft will be taken to size B.

This at first may seem unnecessary, but such is not the case, since by doing so it enables us to set the cutter-bars to a standard size when boring bearings; it also prevents the possibility of error in erection which might occur where journals and bearings were of sizes varying in thousandths of an inch.

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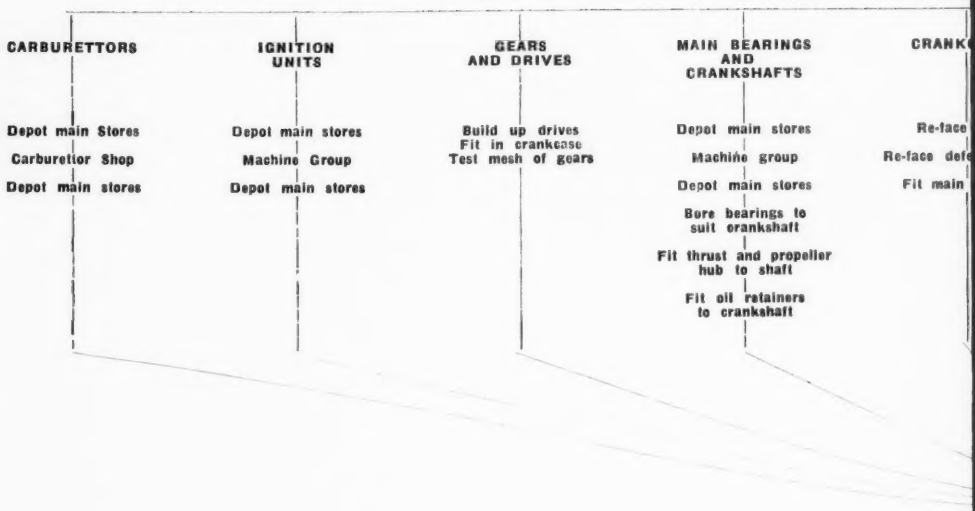
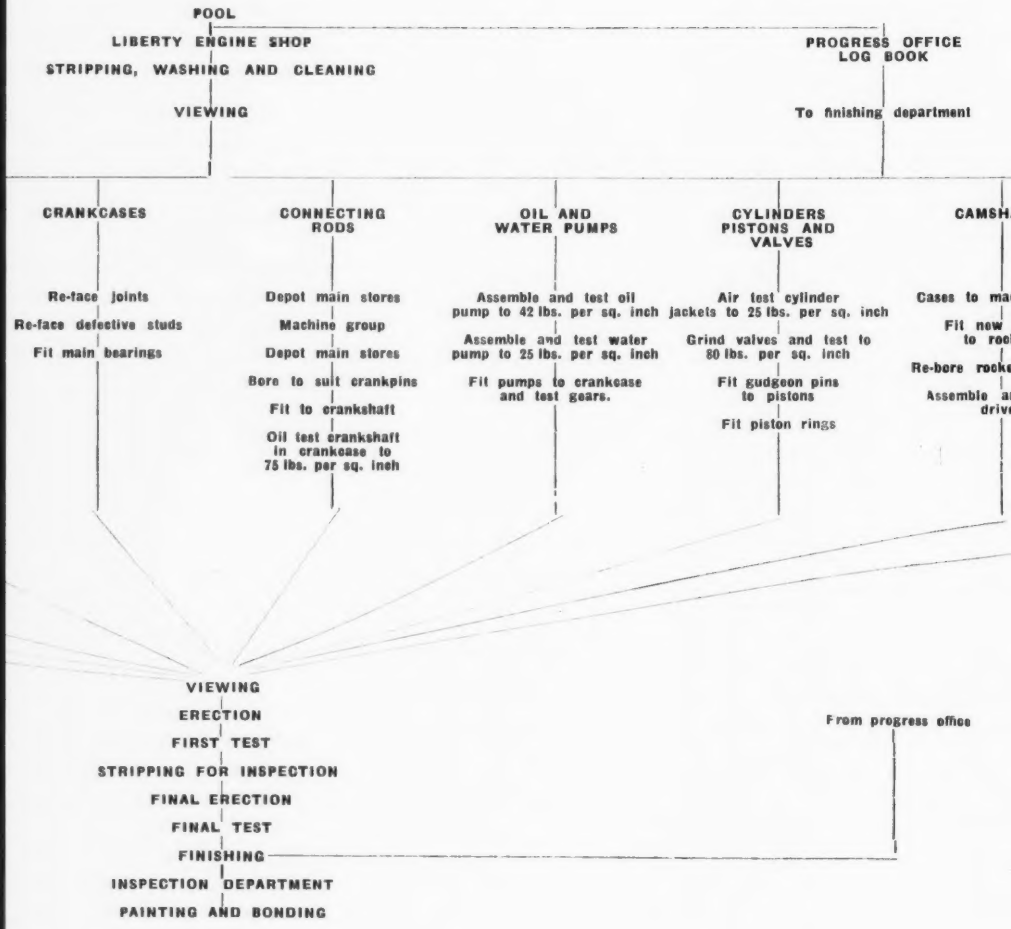

CARBURETTORS
Depot main Stores
Carburettor Shop
Depot main stores
IGNITION UNITS
Depot main stores
Machine Group
Depot main stores
GEARS AND DRIVES
Build up drives
Fit in crankcase
Test mesh of gears
MAIN BEARINGS AND CRANKSHAFTS
Depot main stores
Machine group
Depot main stores
Bore bearings to suit crankshaft
Fit thrust and propeller hub to shaft
Fit oil retainers to crankshaft
CRANK
Re-face
Re-face defe
Fit main

CHAIN OF OPERATIONS



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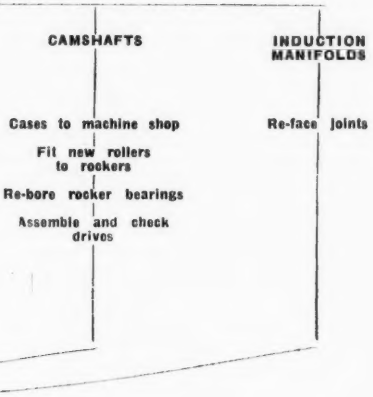


ess office

Assuming an engine does 200 hours between overhauls and the crankshaft required stepping down at each overhaul, the crankshaft would have a life of 1,200 hours, which is considerably in excess of the average life of an aero-engine of to-day, but possibly not of to-morrow.

On completion of the operation, it is first viewed and checked by the N.C.O. in charge of the grinding bay, and then it goes to the general view room of the machine shop, where it is again checked before being returned to the main stores, where it is ready when required for issue.

Main Bearings.—These are viewed and fitted to the crankcase, and are bored to suit the shafts. The oil retainers are fitted to the shaft, which is then replaced in the crankcase, complete with its thrust, and is checked for side clearance.

The maximum diametrical clearance is now given to the bearings, instead of the minimum, as formerly. It is estimated that this will greatly increase the life of these bearings. An oil pump is used to lubricate the tools of the boring bar, and to keep swarf out of the oil ducts.

Radiusing tools are used in the boring bar, for getting fresh radii on the bearings. The main bearings are not burnished, as it has been found that the finish after boring is perfectly satisfactory. This also effects a further saving in labour. The crankshaft gear and double bevel wheels are now fitted.

Operation No. 5—Crankcase

The crankcase is viewed and inspected for cracks, soundness of studs and main-bearing bolts; clear oil galleries, distortion, etc. If extensive cracks are found in the webs, the crankcase is usually scrapped.

Operation No. 6—Connecting Rods

Connecting rods are drawn from the stores, viewed and tested for twist and bend. They are bored to suit their shafts, fitted, and tested for side clearance. The shaft is replaced and meshed to the timing marks; the crankcase is then bolted up and oil-tested to a pressure of 120 lbs. per sq. in. The crankcase, complete with oil and water pumps, gears, connecting rods, and big ends, is now ready to pass to the erectors. The rods are now numbered with the numbers on the starboard side of the engine, and the bearings with their numbers all facing forward.

This greatly facilitates re-erection after the test.

Like the main bearings, the big ends are now bored with maximum clearance instead of minimum, as before.

The big end boring jig has now been altered to take 0.010in. oversize bearings. A new jig is, however, under construction, and will accommodate various sizes.

These bearings are also no longer burnished, and are radiused in the same jig in which they are bored.

Operation No. 7—Oil Pump

This is stripped and viewed in its own bay, and any repairs carried out. It is then re-assembled and tested by means of a hand-operated gear drive, which turns the pump at approximately 750 revs. per minute, being about half that at which it normally works when in the engine.

The relief-valve is adjusted and tested to 30-35 lb. per sq. in.

Water Pump.—This is stripped, viewed, and tested.

The gland spring is tested; the pump is then tested for delivery, 100 gallons per minute at 1,700 revolutions, again approximately normal speed at engine revolutions.

Water and Oil Pipes.—These are sent to the coppersmiths' shop, where they are cleaned and tested to 10lb. pressure.

All rubber connections are scrapped, and new ones fitted. Wooden templates are used for this purpose, so that all joints of a type are of standard length.

Operation No. 8—Pistons and Cylinders

Pistons are weighed in sets after the gudgeon pins and retainers have been fitted. Rings with correct clearances, *i.e.*, gap 0.021in. to 0.049in., and side 0.002in., are then fitted, and the complete pistons are then put up in boxes ready for the erectors.

Originally all pistons were lapped into cylinders, but this has been found unnecessary, provided that the rings have been properly selected and tested before use.

Cylinders.—New or re-conditioned cylinders are drawn from the stores, viewed, water jackets tested (air test of 25 lb.), fitted with valves and springs which have been tested ror compression under a given load of:—

Exhaust valve outer ... ... 45lb.
Inlet valve outer ... ... 25.5lb.
Inner springs 26lb., compressed to 2.25in.

Old valves are sent to the machine shop for re-conditioning, and when finally used in the erecting bay are lightly ground in their respective cylinders.

The cylinder is then bolted to an adaptor, air pressure of 80 lb. is turned on from a compressed-air system, the valve ports are filled with paraffin, and the leakage inspected.

Operation No. 9—Camshafts and Camshaft Casings

These are viewed for the following points:—

Cracks in casing, condition and size of gears, condition of shafts (*i.e.*, tool marks, etc., between cams), worn cams, pitted cams, bowing of shaft and distortion of flange and bushes.

Complete sets are passed to the camshaft bay, and the following operations are carried out:—

1. All casings and covers are scraped and ground with water paste, to ensure oil-tight joints.
2. Rocker bearings are reamered.
3. New rollers to rockers and new tappets.
4. Rockers are fitted to casings, and put up with correct diametrical clearance and end play.
5. Bearings are fitted to shafts and casings.
6. The whole is assembled, and the upper driving shaft is fitted. Gears are meshed correctly, to timing marks.

NOTE.—Driving flanges are now ground to minimum thickness, to allow of correct backlash being given to the gears.

Previously, a method of selection by trial and error was employed, and often a day would be wasted in selecting a gear giving the correct amount of backlash. A modification to the end of the bush has also been carried out, by which the position of the locating hole for the locking stud has been moved; a few of these modified bushes are always held in reserve. By these two methods alone, an immense amount of time has been saved in the erecting of camshafts.

Small gauges are used for fitting the casings and caps, and special extractors have been made for removing the gear wheels.

Operation No. 10—Induction Manifolds and Water Headers

These *are viewed* for cracks, etc., stud holes are re-tapped if necessary, and all faces are scraped. The manifolds are then built up in pairs, and coupled together by water header. Special attention is paid to carburettor ports, as it is sometimes found on inspection that these parts are cracked. All the above is done on a temporary jig built up on an old crankcase, and 6 old cylinders.

The jig consists of two parts, one for fitting up the manifolds, and the other for lining up the cylinders on the crankcase correctly. By this means a pair of induction pipes complete can be fitted complete to any engine.

NOTE.—Under the old system the manifolds were faced up and fitted to the particular engine by the erectors. This was not altogether satisfactory, chiefly because it prevented interchangeability.

Breathers and oil fillers are also examined in this bay, covers are repaired, and the faces cleaned up.

The altitude, carburettors, and ignition control rods are sorted out and fitted up to the correct lengths on a small jig made in the shop for this purpose.

Operation No. 11—First Erection

A gang, consisting of one skilled fitter and one aircraft apprentice, collects the following components ready for assembly:—

1. Crankcase, fitted with shaft, connecting rods, gears, and oil and water pumps.
2. Carburettors (drawn from stores).
3. Generator (drawn from stores.
4. Ignition heads (drawn from stores).
5. Induction manifolds, in pairs, with water headers fitted, water pipes, controls, breathers, oil fillers, and ignition leads.
6. Pistons, rings, gudgeon pins, retainers, and a set of cylinders complete with valves.
7. C.C. gear for the gear bay.
8. Camshaft complete from the camshaft bay.
9. All joints and washers issued with the parts concerned.

The system by which each stage of the erection is inspected and passed has already been described.

The order of erection is as follows:—

1. *Pistons* checked for correct rings, spacing of gaps, fit, and clearance of rings; fit of gudgeon pins and retainers.
2. *Cylinders* are fitted, and paper washers examined. Induction ports are aligned, to .002in., and camshaft bosses lined up to .002in.
3. *Induction Manifolds* fitted, carburettor flanges are checked, and positioning and fit of water headers examined.
4. *All Water Pipes* are fitted, and water system tested to a pressure of 20 lb. per square inch. A new type tester has recently been made for this purpose.
5. *Ignition Lead* carrier assembled and positioning, numbering, and length of leads examined.
6. *Generator* fitted and checked for correct fit of spigot on generator drive ball bearing.
7. *Breathers* and oil fillers fitted and examined.
8. *Carburettors* put up, joint inspected, and controls adjusted for length and free working.
9. *C.C.* gear fitted.
10. *Camshafts* fitted up to marks, timing checked, and clearances adjusted to within .002in., .015in. for inlets, and .019in. for exhausts. A tolerance of three degrees late or early allowed on timing. The timing *pointers* are now fitted, and the top dead centre position is accurately found on the timing disc.
11. *Ignition Heads* are fitted, timed correctly and checked. These engines used to be timed by means of pieces of cigarette paper between the platinum points for synchronising purposes. This method has since been dropped, and a system of lamps with a small battery is used instead.

12. *Ignition Controls* and leads are connected up and examined, and the engine is then ready for test.

Operation No. 12—First Test

After a movement order has been obtained the engine is taken down to the test house, with the exhaust ports covered up. It is fitted to the propeller bench, and the first test is carried out as follows:—

Running In.—All engines must be run in light for a period of not less than one hour until free, either under their own power, or town gas, or being driven from shafting, or some other source of power; the r.p.m. of the engine being at the discretion of the contractor.

Tuning Up.—All engines must be tuned up on petrol fuel for at least a quarter of an hour before endurance tests, and five minutes before final test, during which time the contractor should verify that the engine will open up to full power and will also run slowly.

Endurance Test.—Repair engines will be run for one hour, and rectification engines for at least half an hour at normal r.p.m., and 90 per cent. full power (unless otherwise specified) except for the last five minutes, when the engine will be run at full throttle.

The engine is started and checked for slow running. The carburettors are merely adjusted sufficiently to enable the engine to run evenly. This test is only for running in the engine, and for finding minor faults, such as leaky joints in crank case induction pipes, etc. Oil pressure and temperature are noted. Water temperature and petrol consumption (by flowmeter) are checked.

All faults found are noted on the test reports, for rectification by the shops. The engine is run up to about 1,450 r.p.m., and the running in period consists of about 2 to 2½ hours in all.

The engine is then removed from the bench and returned to the shop.

Operation No. 13—Inspection After First Test

On being returned from first test, the engine is placed on a reversible stand. The camshafts are removed and sent to the camshaft bay for examination. Carburettors are also removed and any adjustments noted by the department are carried out by the carburettor shop.

C.C. gear and generator are removed. The sump is taken off, and the following points noted:—

Side clearances between small end and gudgeon pin bosses are checked before rods and pistons are removed from cylinders.

Tightness of generator drive ball race. Correct fit of thrust distance pieces, and then all connecting rods are removed and the following points inspected:—

Soundness of big end and plain rod bearings.

Piston rings for blowing, and pistons for wear.

Connecting rod bolts for stretching.

Pistons are de-carbonised.

Any work that has to be done on connecting rods or bearings is carried out by the connecting rod bay.

On main bearings, high spots are removed as necessary.

Crankshaft is removed and examined on bearing surfaces, fit of thrust, and condition of crankshaft bevel.

All oil retainers are tested for tightness.

Valves are taken out, and cylinders de-carbonised.

Valves are cleaned, and re-ground on their seats.

Water and oil pumps are removed and examined.

Gears are inspected, and any defects found in any of these components are rectified by the men in the bays concerned.

All studs, joints, and water connections are examined. Engine now ready for re-erection.

Operation No. 14—Re-erection After First Test

The N.C.O. in charge of this operation inspects the following points as each operation is carried out:—

1. Cleanliness of all parts.
2. Re-fitting of inlet and exhaust and inlet valves.
3. Pistons and rings.
4. Studs on crankcase, cylinders, induction manifolds.
5. Main bearings re-fitted in crankcase, and checked for correct positioning. Fit of generator drive ball race in housing noted.
6. Crankshaft is replaced and meshed to marks.
7. Fit of thrust in its housing checked.
8. Connecting rods and pistons replaced and bolted up, checked for positioning, according to the numbers and split pinning.
9. Float of oil pump spindle between double bevel and oil pump is checked for freedom, to ensure that it is in correct alignment.
10. Joint between crankcase and sump inspected.
11. Main bearing bolts inspected for split pinning.
12. Water pumps replaced and system tested to 20lb. per square inch (water).
13. Camshafts replaced to marks on drive shafts. Timing checked on timing discs, valve clearances re-set and checked. While camshafts are in the bay, the rocker covers are removed, and all parts washed to remove any traces of the grinding compound which may have worked itself out of the faces during first test, if they have been hand-fitted.

    Other points checked in this way are:—Mesh of the gears; fit of shaft in its bearing; signs of lack of lubrication; and wear of cams, rollers, and tappets.
14. Ignition heads are inspected and replaced. Engine timed by lamps as before.
15. Generator is replaced, and checked for fit of spindles and ball bearings.
16. C.C. gear is replaced.
17. Carburettors re-fitted and their joints inspected. Controls fitted and tested for working.
18. Oil pipes to camshafts are fitted and tested, and all split pinning checked.

Operation No. 15—Final Test

The engine is now placed on the Heenan and Froude water brake and the final test is carried out. This test is usually of about one hour's duration.

The engine is thoroughly warmed up and adjusted for even running. Oil temperatures and pressures, water temperatures, etc., are noted.

When the engine is running satisfactorily, it is open up to 90 per cent. full throttle, and the brake is loaded to keep it running steadily at 1,650 r.p.m.

Power, and petrol consumption curves are taken, and any adjustments to the carburation are made.

At the conclusion of the power test the engine is tested for slow running. All oil is removed from the engine. It is now removed from the bench and returned to the shop for finishing.

Operation No. 16—Finishing

Having successfully passed its final test, the engine is cleaned down externally, and the following points attended to:—

All external split pinning is checked. Propeller hub nuts and bolts completed and their split pins attached. Locking of the hub and thrust nut is checked.

Oil plug on sump securely fastened. Camshafts are properly pinned. Cylinder bolts tightened down. Main bearing stud nuts checked. Induction manifolds examined for cracks, and nuts properly tightened up.

Water pipes and connections inspected and headers examined for cracks, etc. Carburettor control rod fork ends in " Safety " position, and security of lock nuts checked. Rubber ends fitted to H.T. leads. Dummy plugs fitted. Water pump drain cock tab washer secured. Exhaust ports covered by boards, and all nuts and split pins attached. Oil and water outlets and inlets covered with grease-proof paper. Air intakes covered with paper. Engine properly numbered.

Engine is now ready for inspection by H.I.D. inspector, and any points raised by him are inspected. When the engine has satisfied, it is passed to details shop, where it is painted and bonded, and one pint of oil is put into each cylinder. The engine log books are now made up from the Record of Overhaul Book, power curve graph is pasted in, showing what engine did on test, and the log books are inspected and signed. The engine is now ready for despatch, and is passed to engine pool.

NOTE.—No engine or component is considered serviceable until all modifications have been incorporated.

Particulars of all modifications are kept up to date on the boards used for this purpose in the shops.

Comparative Chart

It has not been possible to take an equivalent number of each engine in drawing up the table, therefore the comparison is not entirely correct, but it is sufficiently near to show that there is very marked difference between the various types in several respects.

Engine Water-Cooled " A " has for some time been in service, and it is therefore well known to pilots and mechanics and has been free from any major modifications for some years, and has proved itself an extremely reliable engine so far as present-day engines go.

Engine Water-Cooled " B " has been in service about the same time as *" A "* and therefore is equally well known by pilots and mechanics, but it is not the same standard as water-cooled *" A,"* as the table shows.

Engine Water-Cooled " C " has not been in service as long as *" A "* and *" B,"* and pilots and mechanics have a considerable amount to learn concerning its maintenance; it is also still passing through modification stages, which necessitates numbers of engines being returned to workshops or the factory before they have had an opportunity of completing really long periods; this has the effect of lowering the average for the remaining engines. It is, however, an extremely good engine, and will no doubt show a greatly improved overhaul data chart during the next twelve months.

Engine Air-Cooled " A."—A rather small number of these engines have so far been dealt with by Henlow, but so far as can be seen it is the type of engine which can be readily overhauled completely by Squadrons without returning to depot.

Engine Air-Cooled " B " as at *" A."*

Engine Air-Cooled " C."—Details not at present available.

So much for the present. What of the future? All other points in regard to engine efficiency, etc., being equal. The engine of the future must be one which can be entirely and readily overhauled by Squadron personnel. The expenditure on transport alone of engines from Squadrons to depots or factories is alone no small item, and is considerably accentuated in overseas commands where it is sometimes as much as nine months to a year from the time the engine is removed from the machine, packed, shipped, repaired, re-shipped and re-fitted into the machine; this necessitates increased engine establishments to cover engines " in transit."

	Water-Cooled Engine "A"	*Water-Cooled Engine "B"*	*Water-Cooled Engine "C"*	*Air-Cooled Engine "A"*	*Air-Cooled Engine "B"*	*Air-Cooled Engine "C"*
Maximum time run before complete overhaul.	267 –55	294 –35	254 –25	388 –20	258	338
Average time run by new engines before first overhaul.	108 –9	124 –10	93 –41	204 –55	201.1	198.3
Average time run after overhaul.	154 56	82 –12	79 –41	No engines yet received after first overhaul.	No engines yet received after first overhaul.	...
Hours taken per overhaul.	877	470	1315	500-600	417	None repaired by R.A.F.
REASONS FOR OVERHAUL. Time expired.	64%	35%	22.5%	60%	52%	76.25%
Machines crashed. Not due to engine trouble.	20%	19.3%	16.25%	8.4%	44%	10.9%
Bearings.	10%	18%	7.5%	8.4%	...	...
Water Jackets.*	See average time run.	See average time run.	See average time run.	See average time run.	See average time run.	See average time run.
Cracked or distorted crankcases.	...	4%	6.25%	8.4%	...	...
Broken con rods.	...	4%	3.75%	...	...	...
Miscellaneous. Including Modifications.	6%	19.7%	44.65%	14.8%	4%	12.85%
Totals.	100	100	100	100	100	100

* Although very few engines have definitely failed through leaking water jackets, large numbers have come in prematurely for overhaul owing to the heavy call on labour falling on squadrons in carrying out replacements of the faulty cylinders.

The money so spent could advantageously be applied to an increase of Squadrons, and further the purchasing of what should be an unnecessary engine is uneconomical, especially as types so rapidly change. Is the detailed design of aero engines progressing along the right lines? Can it be considered satisfactory that the most an engine will run, *with very careful nursing*, is about 400 hours between overhauls? (and this is an extremely liberal estimate). From a Service point of view the overhauling of engines in an unmitigated nuisance. It entails the setting up of workshops in the field. The waste of many years of a man's service in training him for this highly skilled work. The provision of extra personnel for overhaul work apart from maintenance. The provision of large stores with its attendant storekeeping and accounting personnel. Can we not have an engine to run at least 1,000 hours without overhaul? Such an engine would, in time of war, outlast the aeroplane, and so solve the problem of overhaul.

We have travelled very far on the " weight per horse-power " road; is it not time we considered efficiency as measured by the number of useful hours an engine will function, together with the minimum of attention and the ease and speed with which it can be overhauled?

It is within most of our recollections that the automobile engine was once in the same position as aero engines are to-day. True, the automobile engine is not stressed in the same way as an aero engine, but to-day practically any car engine will run 12 months without lifting the bonnet provided oil and water are supplied. Cannot the aero engine be brought to the same pitch of reliability? I certainly think that very great strides have been made in aero engine work during the past 16 years, and I well remember certain aero engines averaging 13 hours between overhauls.

I see no reason why the *thousand-hour engine* should not appear within a comparatively short time.

Discussion

Mr. Roy Fedden, in opening the discussion, said: I think the most arresting statement in the paper is that " If intensive operations are long continued, the question of the repair of aero engines being used for attack or defence may easily become of vital importance." This brings to mind a sentence from a lecture by Air-Marshal Trenchard two years ago before the Cambridge University. In this he said, " In the event of another war the wastage of aeroplanes would be so great that that country which could most rapidly re-equip itself would most probably win the war." I would suggest that the author should add after repair the words " supply and maintenance," and it is largely because of this consideration that I concentrated on the air-cooled radial engine some years ago, even when its commercial prospects seemed very poor.

There are three broad questions which come within the scope of this paper. The first is the training of service personnel. I submit that service overhauls will never be as efficient as trade overhauls until the service gives as much time and consideration to the training of the men as the trade does, though the author has done really magnificent work at Henlow during the last two or three years to raise the standard of workmanship and to train apprentices properly. I submit that the fault really lies with the Air Staff, which appears to think that our really difficult branch of internal combustion engineering should be a sideline to rigging, wireless, guard and fatigue duty, and so forth. If we are to have aero engines maintained in a really first class manner, then it will be necessary for the Air Staff to adopt a policy of decentralisation and specialisation and to train men in the proper manner. The Air Staff must realise that the business is a highly specialised one, and that if the trade cannot have more than a certain percentage of apprentices, neither can the Air Force. As an instance of the need

for the Air Staff to appreciate that this is a special branch of engineering, I will quote the following case. A certain squadron was sent out with two makes of air-cooled engine to a very hot and dusty climate, and as the R.A.F. personnel had never seen this engine before I was allowed to send out one of my foremen. In due course one of the machines with our engine had completed 125 flying hours, and as this was some hours above the usual it was decided to strip and examine the engine. This was done by a gang of R.A.F. men under the supervision of my foreman, and an elaborate examination and report made. When it came to supervising the re-erection of the engine, however, my foreman found that the non-commissioned officers and all the men who had assisted in stripping the engine had been detailed for guard duty and would not be back at all, and a new lot of men were put on the job. I should like to tell the author, on behalf of the engine makers, that we should welcome his sending men to us for longer periods. I should like also to see some of his N.C.O.'s stay, if possible, for two months, and we are always delighted to see them, because we are certain that anything we are able to teach them will be of advantage to us as well as to the Service.

The second point I want to bring forward is, engine life between overhauls. In one part of the paper the author says that 100 hours is the average at present, and then he asks us to get ready for 1,000 hours. I fear our confrères in the motor trade will feel we have not done a very great deal if we cannot do better than 100 hours between overhauls. I know the author's statement is based on the Liberty engine which was designed twelve years ago, and was an extraordinarily good engine in its time, but we have records of much longer periods for modern engines. For instance, the *Times* report of January, 1928, on Imperial Airways' Indian services, gives 137,000 miles flown by 23 engines without any forced landing, and the average time between overhauls exceeds 250 hours. I have just had a letter asking whether they might run for 500 hours without overhaul as a trial. I have also a letter from the Chief Engineer of the K.L.M., the Dutch Air Line, saying that he uses 9-cylinder air-cooled engines only, and that the Van Lear Black engine last year flew 18,700 miles without overhaul or trouble of any kind, and had then completed a thousand hours' running. The letter goes on to say that this is not an exception. The Dutch Air Line has in service seven Jupiter engines which have done more than 1,000 hours, and one of which has done 1,315 hours, and they are giving every satisfaction, the average period between overhauls being 250 hours. It is also added that whereas the operating costs with the air-cooled engine were 1.35 florins per ton-km., those of similar machines with water-cooled engines were 4.6 florins.

So far as British aero engine development is concerned, I think it will take some time before we can make engines which will run 1,000 hours between overhauls, although we can do somewhat better than 100 hours. With regard to the 1,000-hour engine, we are delivering to the Air Ministry modern air-cooled engines weighing 1.75lb. per horse-power, and we have engines on the stocks weighing $\frac{3}{4}$lb. per horse-power, but I suggest that whilst these low weights are fixed it is going to be very difficult indeed to get 1,000 hours between overhauls. The search after exceedingly low weights means that we have to grind the inside of the bores of the crankshaft and grind the wire of our valve springs before we wind it, and etch all our connecting rods for failures and possible slag inclusions, and treat our pistons with special caustic soda baths for cracks. While raw material is in its present state and we have to build down to these low weights, it is absolutely necessary to take these precautions. However, I submit that with the air-cooled engine we have got the overhaul periods up to 250 to 300 hours, but I am afraid that until the author can give us an increase of 50 per cent. in weight it is going to be very difficult to get the 1,000 hours between overhauls with our present knowledge of materials. I suggest that in order to get this period of overhaul we shall have to go very strongly for non-ferrous forgings.

We are going in for drop-forged crankcases and pistons to-day, but we shall have to adopt drop-forged cylinder heads also, either in duralumin or " Y " alloy.

Then with regard to the correctness of the policy that future aero engines should go to 1,000 hours between overhauls, again I say that this rests with the Air Staff. The engine designer is on the horns of a dilemma, because it takes two or three years to develop an engine, and he does not know how often the Air Force policy is going to be changed. I think we shall have to try and get the Air Staff, when looking at the performance of our aircraft, to realise also that an important factor is, how long the machine will take to make and repair under war conditions. Only a few years ago a certain section of the Aircraft Press stated that our single-seater scouts were out of date and 25 miles per hour slower than the American scouts. Last year I was in America and visited a Pursuit Group which had these particular machines, and the officer in charge of repairs agreed that his machines were certainly faster than ours, but they were absolutely impracticable, and in war could not have been kept in the air. I was then shown in another shed the eighth edition of this same machine, and this was fitted with the air-cooled radial engine, and although the performance was 14 miles per hour less than that of the prototype, the Chief Workshop Officer, who held a similar position to that of the author at Henlow, told me that this was the ideal type of machine for general purposes to-day, because it made the engine overhauls and machine construction so simple.

In conclusion, I would remind the author that if he uses single-row radial bearings with centrifugally-cast white-metal solid bronze bearings, he need not run in his white-metal in the shops at all, because he can keep a range of sizes and take the bearings off the shelf and replace them without elaborate fitting. These bearings last as much as 800 hours. With regard to overhauls, I think the practice described in the lecture is rather dangerous from the engine designer's point of view, because I do not like to see all the used parts mixed up in this way, and all track lost of the life of components, but I suppose this refers to the Liberty engine, where these things have got to such a state of standardisation that it is not necessary to keep them separate and logged.

Engineeer-Rear-Admiral W. R. PARNALL: My activities have been amongst engines of a very different description from those mentioned in the paper. The author has described his job at Henlow as being primarily a training place for mechanics, but he seems to have made a sort of mass repair job. I should never have imagined that there was any method of repairing machinery which followed mass production so closely as he has shown. The aero engine has a comparatively short life compared with the engines which I have been accustomed to, and which run not for 100 hours, but for several thousand days before being put on the scrap heap. Therefore we do not require for our infrequent repairs the jigs and gauges, or the hand-worked tools for reproduction of the gauge sizes which the author has described. The latter is a most interesting development and reflects extraordinary credit on the ingenuity of the officers of the Air Force in adapting mass-production methods to mass repair.

Major G. P. BULMAN: The paper raises two fundamental points, namely, design and personnel. I am in agreement with the author that in the choice and direction of development of engines, facts other than pure output and efficiency must be taken into account. Aviation, although perhaps the most scientific of engineering pursuits, probably gives the greatest scope for the science of economics, and although such factors as ease of repair, cheapness of maintenance and production are not spectacular items in the performance of the complete aircraft, yet taking a broad view, these factors are at least as important as, and in some cases even more important than, the fundamental efficiency of the design. On the matter of personnel I think our sympathies will go out to the author in having to repair engines and maintain output—at the same time to train mechanics

—with such an enormous variety of untrained men compared with the number of trained mechanics available, but I must confess that I feel a little uneasy as to whether, in the training of the mechanic, he is really getting the engineer. It seems to me that the author's scheme legislates rather for the man without any imagination, in fact, with very little intelligence and with the whole procedure boiled down to charts giving tolerances, etc., which have to be observed. It seems to me that the system is developing a man who fits up things with clearances of 0.005in. or 0.007in. because they are on the paper, but who does not know what 0.005in. or 0.007in. really means, or what would happen if the tolerance was 0.004in. or 0.006in. For some years I have had the job of choosing personnel to take some important part in looking after the manufacture of aero engines, and I have found beyond question that the man best fitted for that type of work is one who has never seen an aero engine before. What I mean is that given two men of the same average intelligence, one who has spent all his engineering life on pulling down and putting up aero engines, and the other who has been through a marine shop or locomotive works, and who has never seen an aero engine, it will be found that within three months of taking on the job the non-aeronautical man will show up best. I may be prejudiced, in that I am an old marine engineer myself, but I do think that when we talk about aeronautical engineering we stress the " aeronautical " rather than the " engineering." The " aeronautical " follows the " engineering " pretty quickly, but starting the other way round, the " engineering " does not always follow the " aeronautical." Turning to Table I., I think a good deal of explanation is needed in order to calibrate the various figures. For instance, no mention is made of the kind of duty to which these engines have been put. Thus, if a particular type of high-compression engine is put into a heavily laden machine which just staggers off the ground reluctantly, it will have a relatively low number of hours' running before overhaul is necessary, whereas that same type of engine, put into a scout, which simply bounces into the air and reaches 5,000ft. very rapidly, will probably give twice the number of hours' running. That may have some bearing also on the relative hours of use of the water-cooled and the air-cooled engine before overhaul is necessary. I think, speaking generally, that air-cooled engines are fitted in machines which may have an easier time; that is, they are put into the " bouncing " type of aircraft and not the " staggerers." It would appear that in one case the overhaul has been useful in extending the initial life of the engine, but I should like to know whether the author refers to service overhauls or contractor's overhauls. In conclusion, there is one sentence at the end of the paper in which the author says, " From a Service point of view the overhauling of engines is an unmitigated nuisance. It entails the setting up of workshops in the field and the *waste of many years of a man's service in training him for this highly skilled work.*" I submit, most definitely, that training a man as a craftsman is not wasted effort.

Wing-Commander T. R. CAVE-BROWNE-CAVE: The author has explained how much the repair of engines is slowed down by the fact that he has also to train mechanics. I think at the present time that almost all the mechanics who go through Henlow are in the training list. That is probably a temporary state of affairs, and when our training has been in operation for a greater number of years I imagine conditions will be very much better. I entirely agree with Major Bulman as to the relative merits of the thoroughly trained engineer and the engineer trained to carry out the special processes which the author has described, but what has to be considered is the result which it is desired to achieve. If it is the policy that in war-time we shall deal with engines as they are being dealt with at Henlow, it seems to me that, desirable as it is to be able to afford to give the Air Force mechanics a good general engineering training, mechanics have to be produced to act with the greatest speed and efficiency in order to carry out the kind of work which will have to be done in war-time.

Commander W. BRIGGS: I noticed that in the operation of gauging, a six-throw crankshaft is balanced on two V blocks, one at each end, but I should have thought that the spring in that shaft must make the results very unreliable. Similarly, the camshaft casing is only supported at the ends when being milled, which must also lead to inaccuracy in the centre faces. I think that if the figures in Table I. could be amplified for any particular engine the information would be most valuable to the aero engine manufacturer.

Obviously the ideal is an engine which wears out uniformly and then wants overhaul everywhere after what is considered to be its reasonable life. I think that we may consider that, despite the reduction in the weight of engines generally, the life between overhauls has been tending to increase. For instance, the normal life of main bearings of the Eagle VIII. engines running for a large commercial air line is about 600 hours, and some give 900 hours. The period between complete overhauls is about 300 hours, and that is not a bad life, and it is interesting to compare it with the life of other sorts of machinery. If we consider the aero engine on the basis of 300 hours, a fair assumption is that that engine has done 36 million revolutions, and that the machine has travelled about 30,000 miles. The weight of such an aero engine is about 2¼lbs. per horse-power. With the latest built type of reciprocating ship machinery for an Atlantic liner, now some years old, the normal overhaul is about once a year, and during that time the ship has run probably 3,600 hours, made about 18 million revolutions, and run 72,000 miles, so that although the revolutions are only about half, the mileage is about double, but that machinery weighs something of the order of 80 to 100 lbs. per horse-power. Then let us take a motor-car engine which weighs 10 to 12 lbs. per horse-power. We can assume 40,000 miles' running for a good car before an overhaul is necessary, which means about 1,500 hours' running and about 90 million revolutions, so that on this basis, despite its light weight, the aero engine does compare to-day very favourably with other forms of machinery.

In conclusion, I would ask the author to render available to the manufacturer all the information he possibly can regarding the main and minor sources of shortness of life, and so help them to improve the breed.

Capt. J. S. IRVING: The author states that the average time between overhauls of an aeroplane engine is about 100 hours. Surely this is a very low estimate; aero engines had an average life between overhauls of over 100 hours many years ago, and if this has not been increased I fail to see why the author is so optimistic about the immediate possibility of the engine with 1,000 hours between overhauls. As Mr. Fedden rather suggested, however, unless the demands for exceptionally high efficiency and output of aero engines are somewhat modified, we are unlikely to get an engine for Service work which can be relied upon for much more than 100 hours between overhauls. Commander Briggs mentioned several comparisons with other means of transport, but I do not think these should be taken too seriously into consideration. If an aviation engine is going to give real service under war conditions, then we have either to get near to the 1,000 hours' basis or we must have engines which can be overhauled in very much less time than is required for the present engine. The engine which the author has mentioned as giving a flying life of 100 hours between overhauls, and an average time for overhaul of 500 hours, is really only in service for, approximately, 15 per cent. of its life. Taking 500 hours for overhauling an engine and a squadron with twelve engines, if, as the author suggests, squadrons will have to overhaul their own engines under Service conditions, it will require fifteen men working for eight hours a day for fifty days to overhaul these engines, so that the personnel and equipment of these squadrons would have to be considerably increased. A way out lies in the production of engines which will not only give considerably increased life between overhauls, but which could also be overhauled in very much less time. If we follow up the

analyses of defects given by the author, it will be found that the water-cooled engine is very definitely not the best as regards reliability, and presumably water-cooling is responsible for this very marked difference in running time. I have always been a confirmed supporter of the air-cooled engine since the advent of the R.A.F. 1A and 4A engines in 1914, and there is no doubt in my mind that eventually the air-cooled engine will become *the* engine for general aeronautical purposes, although the water-cooled engine may still be of service for very special requirements. Here, however, it would not seriously affect the question of general upkeep of the R.A.F. equipment, which would be chiefly based on the requirements of the service " General-Purpose " engine, which would be air-cooled, have *perhaps* slightly lower efficiency as regards power output per cubic inch capacity and slightly higher weight per horse-power, but which could be relied upon to run for periods between overhauls more nearly approaching the 1,000-hour ideal suggested by the author, and requiring considerably less than 500 hours per engine when the overhaul did take place.

Col. T. M. HUTCHINSON: I am interested in the remarks made by the author on the question of training personnel, because in the other Service with which I am connected we have experienced much the same difficulty in the provision of trained artificers, and the output of our repair shops has in very many cases been seriously restricted by the necessity for training personnel. I am afraid in the next war we shall find it difficult to provide sufficient artificers to keep in the field all this complicated machinery—not only aeroplanes, but mechanical transport and a large amount of other technical equipment used in the Army and Navy and Air Force. The author has suggested repair by the provision and fitting of replacement parts, such as the substitution of ball bearings for white-metal bearings. That, in a way, is an excellent suggestion from the squadron and field repair point of view, but it means that somebody at the base or behind has got to manufacture these parts, and this in turn involves a considerable amount of labour to manufacture, especially ball bearings, which are not easy to produce in quantity. We know the difficulty we had in the last war. The solution seems to lie in simplification of construction and elimination of the points in design which are causing breakdowns. A good deal of improvement has already been made in mechanical transport vehicles, at any rate, towards increasing their life, eliminating wear, and obtaining more reliable material. I am afraid we must continue to train men, and I anticipate the Air Force, as well as the Army, will have to train their men. To a considerable extent I am afraid this must be a specialised training, because the time we get the men for is so short that the most we can do is to train them for the particular jobs for which we want them.

Flight.-Lieut. R. E. ALLEN: The author stated that there has been considerable trouble in getting satisfactory white-metal bearings which will stand up, and also mentions that the Henlow Depot has dropped burnishing. Would the author give the reasons for that, and give us his opinion as to whether that might not be the cause of the shorter life of the bearings of which he complains? He showed some inlet manifolds being lined up against the port faces of some cylinders, the cylinders being used as a jig. [illegible] assembly of the engine the cylinders were lined up against a straight-edge. I cannot quite see the reason for lining up the manifold against cylinders to which they were not ultimately going to be bolted, and I cannot see why the inlet manifolds could not be bedded to a surface plate. In the test house an electric motor is used for starting up the engines, and I wonder whether use is made of that to ascertain the mechanical efficiency of the engine—in other words, whether it is used as a criterion or whether the engine is " run in " sufficiently to be free, having regard to the wastage necessary to motor the engine round. In Table I. figures are given for machines which crashed, not due to engine trouble; may we ask for figures of machines which crashed due to engine troubles?

Capt. SAYERS: At the beginning of the war I was sent with others to a Royal Naval Air Service engine shop to attempt to overhaul engines which neither I nor any of the Service mechanics at the time had seen before, and the same thing is going to happen to the R.A.F. in the next war. I should like to know where the author's extremely ingenious jigs and hand tools are going to be in these circumstances. As tools they are exceedingly ingenious, but if the R.A.F. is to contemplate a rapid extension on a very much bigger scale than it can bear in peace-time, in the case of war it has also to contemplate dealing with new types of aircraft engines, and I cannot see what use the type of training the author is giving to his men at Henlow is going to be in these circumstances. The man who is going out into distant parts must be ready to take in hand the overhaul of a damaged or slightly defective aeroplane engine of whatever type may happen to be sent to him, and cannot afford to rely on calculated tolerances, jigs, or carefully-designed automatic tools. He has got to be an engineer.

Mr. LIND-JACKSON: I should like to support Major Bulman with regard to the engine hours run between overhauls. I think the nature of the work and the duties imposed on the engines must be taken into account in getting out such figures as the author has given. Obviously an engine which is running for the greater part of its life on nine-tenths power must inevitably require overhaul very much earlier than an engine which is running on half-throttle or half-power, and such figures would be more interesting if the nature of the duties were stated. The relative advantages of air-cooled and water-cooled engines are still a matter of controversy, and such figures may be very misleading unless the exact circumstances are stated. The average air-cooled engine is probably employed chiefly on light scouts, whereas the average water-cooled engine is employed on heavier machines.

REPLY TO DISCUSSION

Wing-Commander FOWLER, in replying on the discussion, said: The paper was intended to deal entirely with the methods of repair work in the Service, and the remarks upon the training of Service personnel were made only to explain certain differences between our methods and those adopted in civilian factories. I would have preferred that the discussion had dealt more with manufacturing processes likely to be of use in the Service rather than with the best methods of producing mechanics. To me, therefore, the most interesting point in the discussion is Mr. Roy Fedden's remark in regard to centrifugally-cast white-metal bearings, which could probably with advantage be applied to types of engines likely to remain in the Service for some time. Here I might reply to Flight-Lieutenant Allen that burnishing was dropped at Henlow partly in order to avoid every possible hand operation, and partly because comparative tests of burnished and unburnished bearings showed no appreciable difference; in fact, the unburnished bearings gave a longer life, perhaps due also to somewhat increased clearances.

Electric motors are used in our test houses for starting up the engines by belting through line shafting. The measurement of power used for motoring engines is, as a rule, only applied to dynamotors direct coupled to the engines, a method which up to the present has not been generally adopted in the Service.

In reply to various speakers, I must emphasise that the figures given in Table I. are only applicable to those engines which pass through Henlow, so that it is impossible to amplify them in the directions asked for, though the figures are doubtless available in the statistical branch of the Air Ministry.

I should also make it clear that 100 hours is by no means the present average throughout the Service between overhauls; two of the engines in Table I. have been in service for many years, and it will be noted that even now the time between overhauls is very low. The third engine is newer, but its time between

overhauls has been influenced by modifications. This disposes of the water-cooled engines. The average of the air-cooled engines is practically 200 hours between overhauls, although these engines are of recent manufacture and still being modified. I see no reason why, within the next year, this average should not be considerably increased.

The remainder of the discussion centred around the best methods of training mechanics for the Service, and I am aware that very many important considerations are involved in the training which a mechanic must undergo to be fitted for use during another war, large or small, and by this test the efficiency of our methods must stand or fall. The remarks made by Major Bulman, suggesting that an engineering training should precede the aeronautical one, have been adequately answered by Wing-Commander Cave-Browne-Cave. It should be quite clear that the object of the Service is not to produce engineers in the steam sense, but mechanics who could be trusted in the field to maintain and to overhaul engines, sometimes under very difficult conditions.

In the Service, Service needs are, and must always be, the governing factor. The majority of mechanics are now, and shortly all will be, apprentice trained. The average mechanic joins for twelve years from the age of eighteen, so that he has eleven years to serve from the conclusion of his apprentice training. This is very different from the twenty-five or thirty years which an artisan may remain with a civil firm. In civil life a five years' apprenticeship and two years as an improver fit a mechanic out for life with the essentials of his trade, and it is considered that the R.A.F. ex-apprentice, two years after his apprenticeship is concluded, is a better mechanic for Service purposes than the corresponding ex-apprentice trained in civilian factories.

In any civilian works of to-day very few mechanics picked out at random would be able to carry out satisfactorily any job upon the engine on which they are working. That is, each man is probably a specialist at some particular job, and could not be transferred without loss of efficiency to any other. In the Service, the ideal is that a mechanic should be able to carry out any and every job upon the engines of which he has been given experience, and this is the only means of meeting war conditions satisfactorily when they arrive.

Perhaps this answers Mr. Fedden's story of the R.A.F. men who stripped an engine down for examination, but who were found to be on guard duty when it had to be erected. In time of war the fitters who had stripped the engine might have gone sick, or might have been blown to pieces by a bomb, and it is absolutely necessary for any mechanic in the Service to be able to take up satisfactorily a job which has been partly carried out by someone else.

I hope, therefore, that it will be realised that the methods of the Home Aircraft Depot are necessarily designed and oriented in order to meet as fully as possible the requirements of training, and for this reason alone the Service could never give precisely similar training to its personnel as if they were in civil life, even if this were desirable or necessary.

Dealing with Mr. Fedden's remarks upon reducing the weight of aero engines, I think it is possible that in the future weight per horse-power will never be the most important consideration. On any engines built for long flights, the consumption of petrol and oil are likely to be far more important considerations, and it is conceivable that it would be of advantage to build an engine heavier if five per cent. economy in fuel could thereby be secured. While on the question of design I should like to think that there is still a field for the air-cooled in-line engine, and believe that multi-cylinder engines of this type are being experimented with in America. This would overcome almost the only disadvantage of the radial, that of the difficulty in streamlining at very high speeds.

We are glad to be able to attach our mechanics to the works of civilian manufacturers, and I have dealt in the introduction to the paper with the advantages of this concession. We feel that the Service has much to learn from modern

manufacturing methods, and it is possible that manufacturers may also be interested in the methods of repair which must perforce be developed by a Service dependent upon them for its very life.

I agree with Major Bulman that the majority of water-cooled engines are used for heavier machines, and that air-cooled engines as a rule are applied to light ones at the present time. The figures in Table I. apply to types of engines whatever their use, and I agree that it is possible that lightly-loaded engines will live longer than heavily-loaded ones. I hope, however, that I have shown that the majority of Service troubles in water-cooled engines are due to jacket leaks and white-metal bearings, and it is possible that these figures would be much the same irrespective of the loading of the engines.

Major Bulman refers to one engine, the life of which is longer between overhauls after its first overhaul than it is when new. I do not quite know why this should be, but have put it down to the engine being a rather roughly-made one, which gives a better life after being run in, or else to increased clearances given after Service overhauls. All the engines dealt with in Table I. are those overhauled at Henlow.

I am afraid that I must differ from Major Bulman as to what constitutes wasted effort. My contention is that when unnecessary complication and short life of engines demands numerous overhauls, the time spent in training skilled labour for this unnecessary work would be better applied to simplification of design and extension of the life between overhauls. If this were done, the highly skilled work would become unnecessary, just as this degree of skill is unnecessary now in civilian life; to that extent the training of such highly skilled labour is wasted. Reform should definitely be in the direction of the improvement of the engine, so that fewer overhauls and less skilled labour would be required.

In reply to Commander Briggs, I am sorry that I did not make it clear that the crankshaft and camshaft were set up for the lantern slides by the photographer, and not by a fitter. I agree that if they were set up as shown, an element of error would be introduced.

I have dealt with the opening remarks of Captain Irving, and agree with him that we must get as near to the 1,000 hours between overhaul basis as possible, and in addition simplify the overhaul so that the standard of skill need not be so high. This is essential where exactly the same personnel is available, whether for repair or maintenance.

Colonel Hutchinson refers to the difficulties we shall experience in the next war of obtaining personnel. These difficulties have already been foreseen by the Royal Air Force, which endeavours to train every man, whether for permanent service or for the Reserve, in such a way that he may be used as a nucleus for the production of skilled personnel from unskilled labour, exactly as the old pre-war N.C.O.'s produced Kitchener's Army at the outbreak of the war. This I take to be the only solution of the difficulties which will arise, and the whole of our methods of aero engine repair are bent in that direction.

Air mechanics nowadays obtain experience on two or three types of aero engines, and whatever type of engine is being worked on, the same kinds of jigs and tools are used. I cannot see that there will be any difficulty in time of war in the application of these simple tools to the overhaul in the field of any type of aero engine.

The men experienced on these tools could produce at short notice other men able to carry out accurately the operations required, even when recruits have little or no mechanical experience. It will presumably be the duty of a proportion of the regular personnel to instruct those required for war-time expansion, and it is conceivable that while the instructors would be able to carry out any job whatever on an aero engine, greater production would be obtained from the recruited labour by making them of one-man one-job class.

THE REDUCTION OF PERFORMANCE TESTS

Lecture delivered before the Yeovil Branch

BY H. L. STEVENS, B.A., A.F.R.AE.S.

I wish to give you to-night some idea of the computing work necessary between the receipt of the performance figures from the pilots and the issue of the complete report.

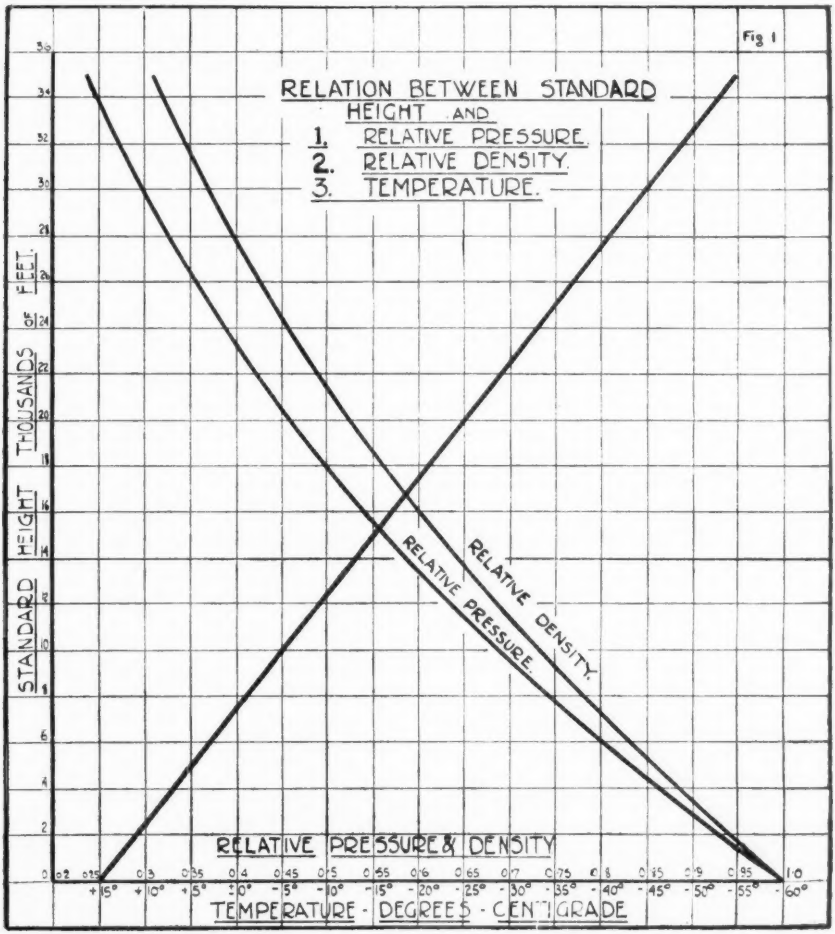


FIG. 1.

The history of a complete set of tests is usually somewhat as follows:—

1. The aircraft arrives and is drained of fuel and oil, and checked against the appropriate Appendix " A " to see how much of the specified load is actually fitted. Meanwhile the airscrew is detached and measured up.

2. It is weighed light.

3. Filled with fuel and oil and re-weighed, and the difference checked against the stated capacity of the tanks, and the fuel put in by " Bowser."

4. These particulars are forwarded to Air Ministry for clearance purposes.

5. The aircraft is ballasted up with all specified equipment, lead being used for items not available, and the centre of gravity obtained. If this is not within the prescribed limits, Air Ministry have to be informed.

6. Preliminary handling trials may take place in the intervals of the above if any delay takes place.

7. Performance tests, consisting of:—

P.E. determination on speed course or by suspended static.
R.p.m. to fly level over whole speed range.
Partials at one-fifth and three-fifths ceiling.
Climb to ceiling and partials at four-fifths ceiling.
Climb to ceiling and speeds at 2,000 feet intervals on way down.
Partials at two-fifths ceiling.
Stalling speed.

8. On the completion of these, and sometimes before the last three are done, the Interim Report is issued.

9. Remainder of performance tests:—

Stick and unstick.
Longitudinal stability.
Spinning and diving tests.
Complete handling trials (including the testing of all taps and gadgets, and the various arrangements of the fuel system).
If time permits A.R.C., stability and control tests, and measurements of fuel consumption.

10. Preparation of complete report.

This looks a pretty formidable list, but under fairly reasonable weather conditions, the interim report stage should be reached in three weeks.

FIG. 2.

PILOT'S TEST RETURN.

CLIMB AND SPEEDS AT HEIGHTS.

Aeroplane and No., Eastland Eunuch.	Date, 17/3/27.
Engine No., J. 6149/103141.	Time, 2.30.
Propeller, G. 4673 N.I.	Pilot's Weight, 180.
Carburetter, 1 Set Bristol Treplex.	Observer's Weight, 180.
Jets, Variable.	Dead Weight, 536.
No. of Aneroid, 37.	Guns, 1 Vickers.
No. of Flowmeter, —.	Extra Weight, —.
No. of Rev. Counters, R.V. 23.	Total Weight, 4747.
No. of A.S.I., H.R.2.	Weight after test, —.
Petrol, 105 Galls.	Oil, 10 Galls.

NATURE OF TEST.

Aneroid.	Time Min. Sec.	Temp.	A.S.I.	R.P.M.	Flows.	A.G.	Rad. In Out	Oil Press.	Temp.	Shutters.
0	—	+ 6	70	1600	—	—	—	—	—	—
1000	—	—	—	—	—	—	—	—	—	—
2000	2.10	+ 6	69	1660	—	—	—	—	—	—
3000	—	—	—	—	—	—	—	—	—	—
4000	5.10	+ 8	68	1660	—	—	—	—	—	—
5000	—	—	—	—	—	—	—	—	—	—
6000	8.20	+ 5	66	1700	—	1/3	—	—	—	—
7000	9.55	+ 3	66	1700	—	—	—	45 lbs.	15°	—
8000	11.30	+ 1	65	1700	—	—	—	—	—	—
9000	13.25	− 2	65	1700	—	—	—	—	—	—
10000	15.00	− 4	64	1700	—	1/2	—	44 lbs.	25°	—
11000	17.10	− 6	64	1690	—	—	—	—	—	—
12000	19.25	− 8	63	1680	—	—	—	—	—	—
13000	21.40	−10	63	1680	—	—	—	—	—	—
14000	25.00	−12	62	1670	—	2/3	—	43 lbs.	40°	—
15000	28.40	−14	61	1660	—	—	—	—	—	—
16000	33.25	−16	60	1660	—	—	—	—	—	—
17000	38.35	−17	60	1650	—	1/1	—	—	53°	—
18000	45.15	−18	59	1650	—	—	—	43 lbs.	—	—
18500	50.25	−19	59	1650	—	—	—	—	51°	—
20000	—	—	—	—	—	—	—	—	—	—
21000	—	—	—	—	—	—	—	—	—	—
22000	—	—	—	—	—	—	—	—	—	—

Throttle not opened beyond gate till 5000 feet passed.

AIR SPEED AT HEIGHTS.

Aneroid.	Temp.	A.S.I.	R.P.M.	Flows.	A.G.	Rad. In Out	Oil Press.	Temp.	Shutters.
18500	−20	74	1710	—	1/1	Beyond	throttle	gate.	
15000	−14	88	1780	—	2/3	,,	,,	,,	
12000	− 7	96	1820	—	1/2	,,	,,	,,	
9000	− 1	104	1840	—	1/3	,,	,,	,,	
6000	+ 6	110	1880	—	0	,,	,,	,,	
5000	+ 7	113	1800	—	0	Up	to	throttle	gate.
4000	+ 7	112	1800	—	0	,,	,,	,,	
2000	+ 7	117	1820	—	0	,,	,,	,,	

Now as to the reduction work that has to be done with the figures.

First of all if only the air were a reasonably straightforward sort of medium and stayed the same from year end to year end instead of blowing about the place and up and down and changing its temperature and pressure whenever one isn't looking there would be no necessity for a technical office and the pilots' figures could be fired straight into the report. Unfortunately, however, the effects I have mentioned all happen and the simple results have all to be reduced to what they would have been if the air had stayed still and been of the particular consistency that somebody has declared to be standard.

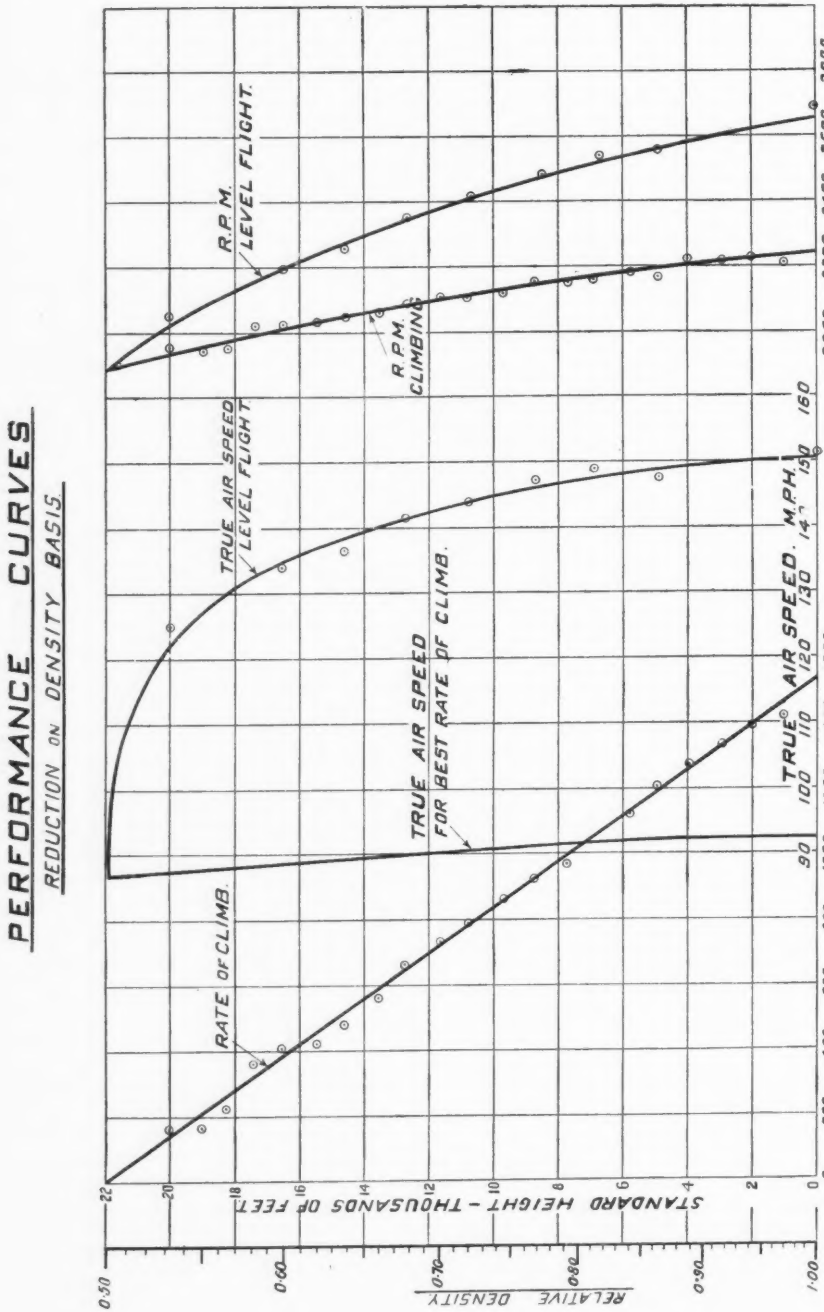

PERFORMANCE CURVES
REDUCTION ON DENSITY BASIS
RATE OF CLIMB.
TRUE AIR SPEED
FOR BEST RATE OF CLIMB.
TRUE AIR SPEED
LEVEL FLIGHT
R.P.M.
LEVEL FLIGHT.
R.P.M.
CLIMBING
RATE OF CLIMB FT/MIN.
TRUE AIR SPEED. M.P.H.
R.P.M.
STANDARD HEIGHT - THOUSANDS OF FEET
RELATIVE DENSITY

FIG. 3.

The most important tests I suppose from most people's point of view are climb and speeds, and for several years there raged a considerable controversy as to the right method for reducing the figures to a standard atmosphere. The arguments turned on whether the b.h.p. of an aeroplane engine depended on the density (which brings in temperature) or only on the pressure of the atmosphere. The method now adopted (for all but supercharged engines) assumes that the power depends on pressure only and an average figure obtained by experience is that the b.h.p. of an engine at height is $p^{1.05}$ where p is the atmospheric pressure at that height. I shall return to this question later.

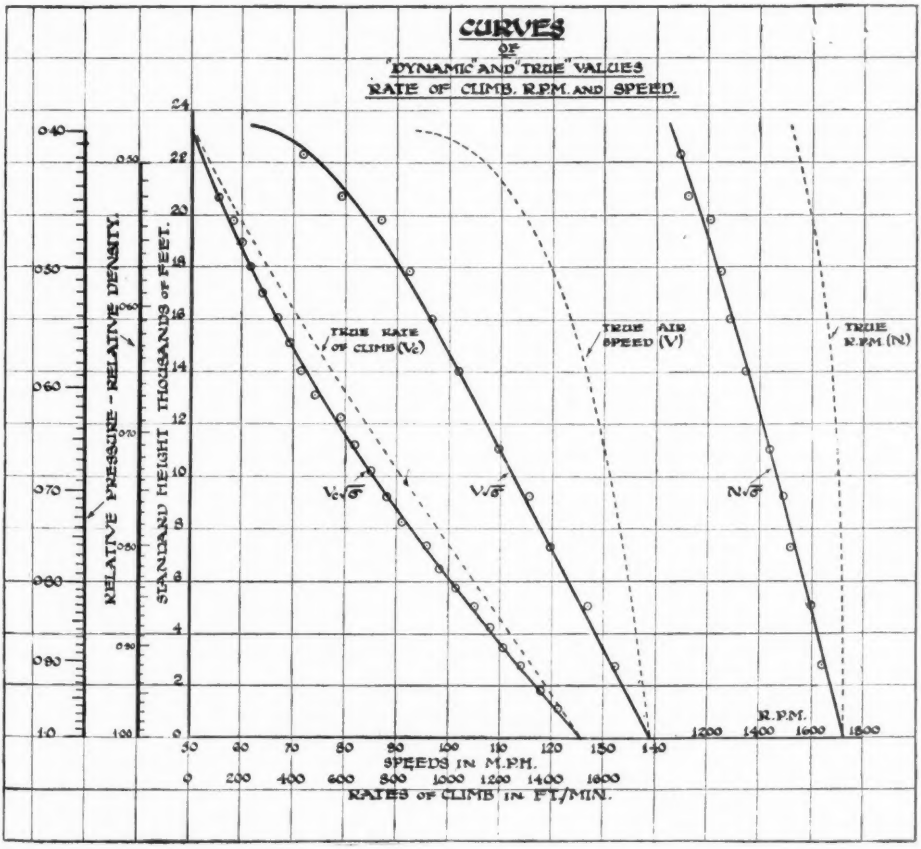


FIG. 4.

The atmospheric temperature has however other effects besides those it may have on the engine. It alters the meaning of the figures on the altimeter by which height is measured in an aeroplane. This instrument is really an aneroid barometer and measures the pressure of the air in which it is placed. For convenience its dial is marked off in thousands of feet, but these readings would only be right if the atmosphere were in a standard condition. It is really weighing the air between the aeroplane and the ground. Now the weight of a

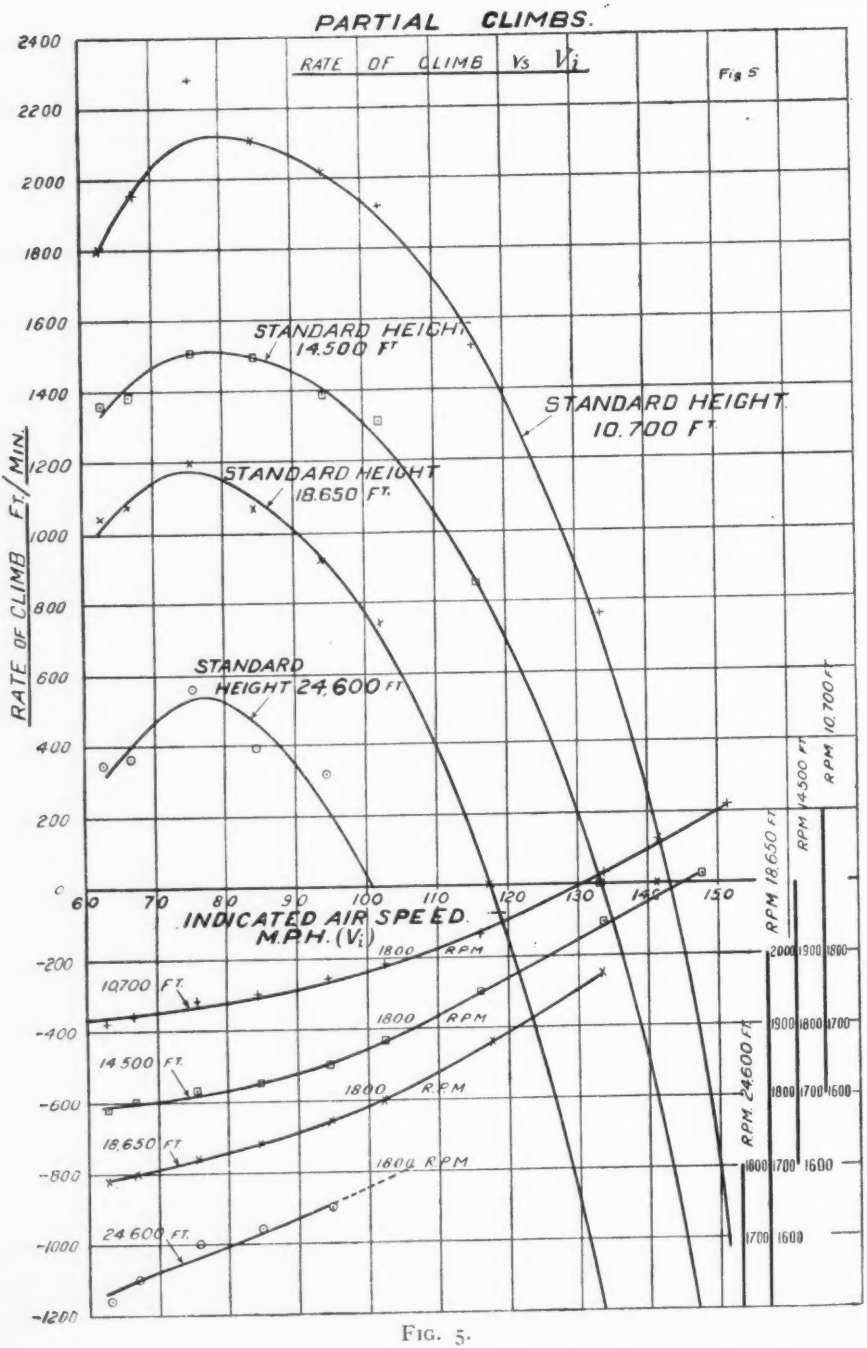

PARTIAL CLIMBS.
RATE OF CLIMB Vs Vi
Fig 5
RATE OF CLIMB Ft./MIN.
STANDARD HEIGHT 14.500 FT
STANDARD HEIGHT 10.700 FT
STANDARD HEIGHT 18.650 FT.
STANDARD HEIGHT 24.600 FT
INDICATED AIR SPEED. M.P.H. (Vi)
10700 FT.
14.500 FT.
18.650 FT.
24.600 FT.
1800 RPM
RPM 18.650 FT
RPM 14.500 FT
RPM 10.700 FT
RPM. 24600 FT.

FIG. 5.

column of air 1,000 feet high will obviously depend on the temperature of the air, or put the other way round, the two weights (or pressures) which are marked on the dial as 1,000 feet apart will only be actually that distance apart if the temperature of the air is the same as that assumed when the relation between pressure and height was calculated when arranging the graduations of the dial. All the older altimeters were graduated on the assumption that the temperature of the air was everywhere 10°C. This was not so bad for low heights, but above about 10,000 feet the instrument was never right. And if it is said you had climbed 1,000 feet and the actual temperature was 0°C., you had actually climbed through $273/283 \times 1{,}000 = 965$ feet because the air was denser than allowed for and less of it weighed the same as 1,000 feet of air at 10°C. Modern altimeters are graduated according to an international standard atmosphere which approximates to average English conditions and will therefore read height correctly on an average day. Its readings will still have to be corrected when the conditions are not standard, but the corrections are much smaller than with the older type and for rough work in Southern England could be omitted.

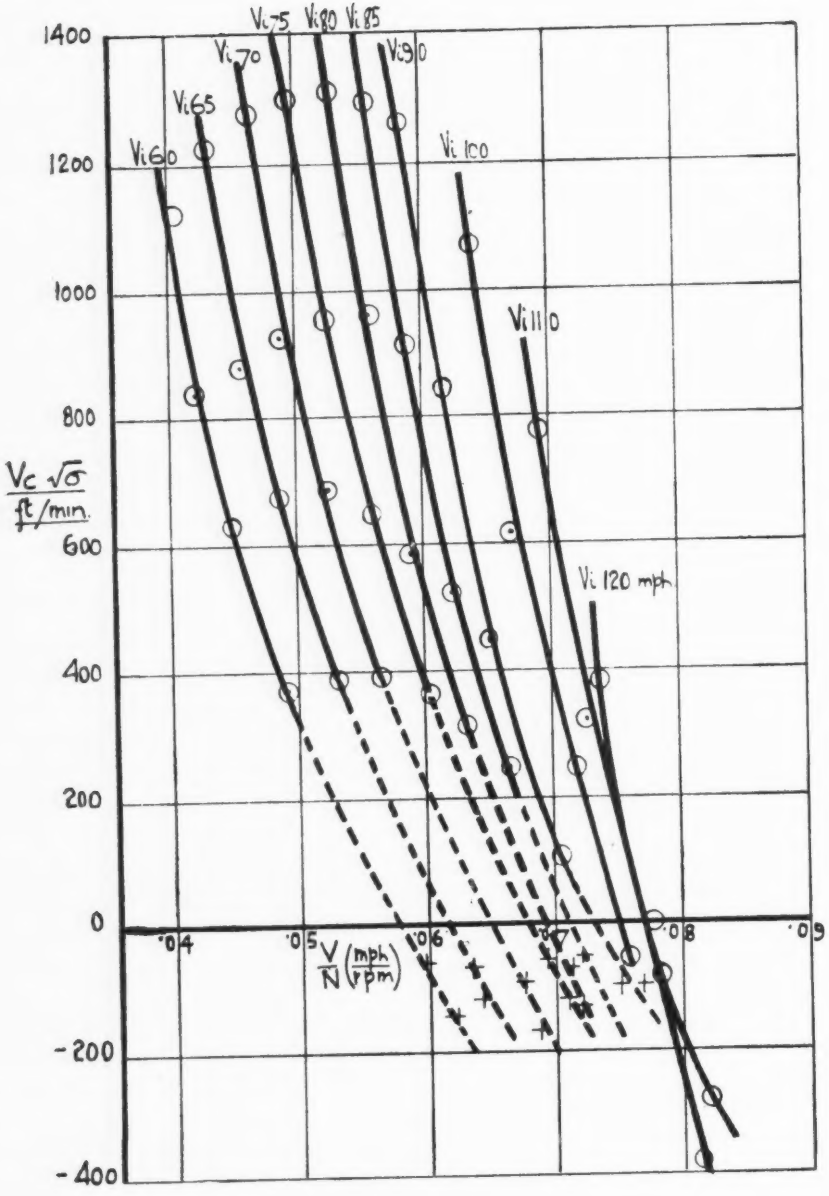
The other important instrument that is affected by atmospheric conditions is the A.S.I. This instrument like the altimeter does not measure either what its face would lead one to suppose. It is graduated in m.p.h. or knots, but what it really reads is the pressure exerted on the open end of the pitot tube on account of the latter being rapidly pushed through the air. Under standard ground level conditions there is a definite relation between this pressure and the speed through the air, and this relation is used to graduate the instrument, but up high where the air is thin the pressure corresponding to a given speed is less or *vice versa* when the air indicator says you are doing say 80 m.p.h. you are actually going much faster. Actually the pressure on the pitot tube is proportional to the density of the air and to the square of the speed of motion through it. Consequently if you are at a place where the air is half as dense as under ground conditions (this occurs at about 23,500 feet—aneroid) you must multiply the readings by $\sqrt{2}$ or approximately 1.4 to get the real answer. On the other hand as the lift of the wings at a given angle of incidence is also proportional to the density and the square of the speed, a certain reading on the A.S.I. will always mean approximately the same angle of incidence and the actual stalling speed will be approximately the same figure on the dial (unless the aeroplane is stunting violently). This is very important as this is one of the most important uses of the A.S.I. apart from test work.

Thus you can see how important it is to have a thermometer on the aircraft. And it must be out in the open, not shielded in the cockpit, or where it can be affected by the heat from the engine.

A further correction has to be applied to the readings of the A.S.I. known as the P.E. correction. This is due to the fact that the aeroplane carries some air along with it, and builds up a pressure at the static head; consequently the readings of the A.S.I. are usually too low. This correction is sometimes found by flying the aeroplane at different speeds over a measured course and comparing the measured speeds with the A.S.I. And sometimes by suspending the static part of the pitot-static head about eight chords below the aeroplane where it is reasonably free from interference.

You can now see that when the temperature and pressure of the atmosphere differ from the standard conditions the performance of the aeroplane will also differ. Thus in order to compare aircraft fairly we must correct the test figures to what they would have been if conditions had been standard.

As I have mentioned already there have been two methods in use for correcting performance tests to standard conditions, the " density " and the " pressure " methods. The former is still used for supercharged engines and as it is slightly easier to explain I will deal with it first.



⊙ EXPERIMENTAL.
\+ EXTRAPOLATED.

FIG. 6.

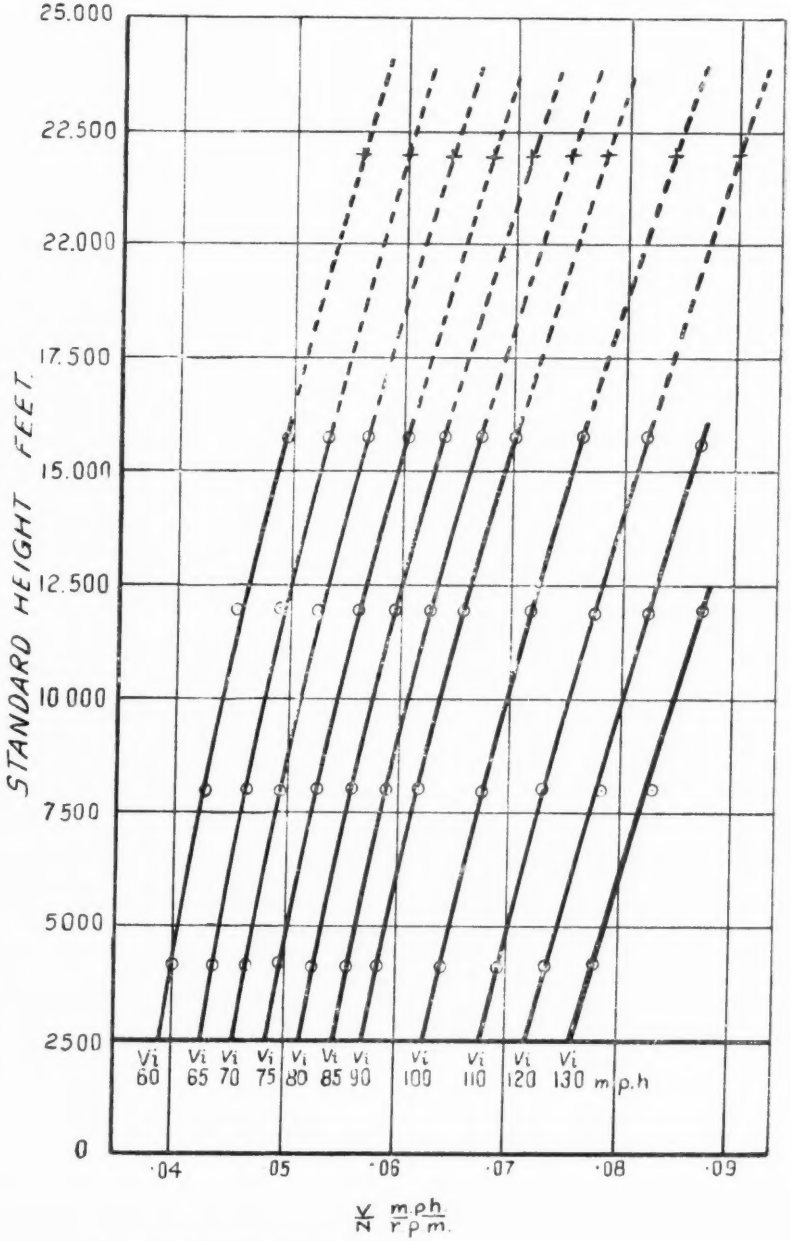

25.000
22.500
22.000
17.500
15.000
12.500
10 000
7500
5000
2500
0
STANDARD HEIGHT FEET.
Vi 60
Vi 65
Vi 70
Vi 75
Vi 80
Vi 85
Vi 90
Vi 100
Vi 110
Vi 120
Vi 130 m.p.h
·04
05
·06
·07
·08
·09
V/N m.p.h./r.p.m.
○ EXPERIMENTAL.
+ EXTRAPOLATED

FIG. 7.

The pilot's test returns reach the office in the form of tables in which the first column gives regular readings from the altimeter. Against these figures are written the time it took to reach them, the air temperature there, the climbing speed, and the r.p.m. Other readings of engine detail, etc., are also included. On the way down from the climb the pilot pauses at a series of heights and flies the aeroplane level at full throttle for three minutes and records the speed attained and the r.p.m. A recording barograph is also carried for these tests.

Now according to the density theory of reduction, the rate of climb, the maximum level speed, and the r.p.m. are dependent only on the density of the air in which the aeroplane is flying. Consequently we extract from the records, at each altimeter reading, the true rate of climb (from the time between successive readings and by correcting the height difference for temperature as explained above), the true forward speed (by correcting for position error and then dividing by $\sqrt{\sigma}$), and the r.p.m. Against each altimeter reading is written the air density actually encountered there. We can then plot a picture of these things against density, and according to the density theory on which we are working at the moment the same picture would have been obtained whatever the relation between density and height. Consequently we have only to write against the density figures the heights at which these densities are obtained under standard conditions to give the performance at different heights on a standard day. Knowing rate of climb against height, the time to height curve immediately follows.

Before explaining the pressure method I want to find a name for quantities such as I.A.S., which is true air speed multiplied by the square root of the density, and I propose to use the term "dynamic speed" on the analogy of dynamic pressure. Thus dynamic rate of climb and dynamic r.p.m. will mean $Vc\sqrt{\sigma}$ and $N\sqrt{\sigma}$ respectively.

Now according to the pressure theory the dynamic quantities and not the actual quantities are dependent on pressure only (*i.e.*, on altimeter reading). Consequently we now extract these quantities from the records and plot them against pressure and, as before, we have a picture which is independent of the atmospheric conditions under which it was obtained. Writing standard heights against the pressure scale gives us the figures in terms of height as before, but a further step is needed here, as for report purposes we want true and not dynamic figures. Hence, we put a third scale of standard density alongside the other two of height and pressure and from it remove the density factor and reduce the picture to one of true rate of climb, speed and r.p.m. against height.

So far we have dealt only with the straight climb and speeds at heights, but before the climb can be carried out the pilot must know the best climbing speed to use at the different heights so that he can get the best out of the aeroplane. To this end short climbs (known as partial climbs), through about 1,000 feet, are carried out at a series of air speeds at several different heights (say 5,000, 10,000 and 15,000 feet). From these, rate of climb is plotted against indicated air speed, and the speed that gives maximum rate of climb determined. If the range of speeds used is carried up to slightly beyond the level speed, the data from these tests forms a valuable check on the straight climb and speeds. These partial climbs can with the aid of certain engine data be made to furnish valuable information on the range of the aircraft at maximum air cruising speeds.

Simple reduction to standard conditions as outlined above is satisfactory so long as the aeroplane engine is behaving consistently and vertical currents in the atmosphere are not encountered. It is possible, however, to analyse the results in a way that shows up any defects on these accounts and enables them to be allowed for.

Under certain assumptions that are fairly well borne out in practice it can be shown that at a given "dynamic speed" the "dynamic rate of climb" is dependent only on the ratio of the forward speed to the airscrew r.p.m. Con-

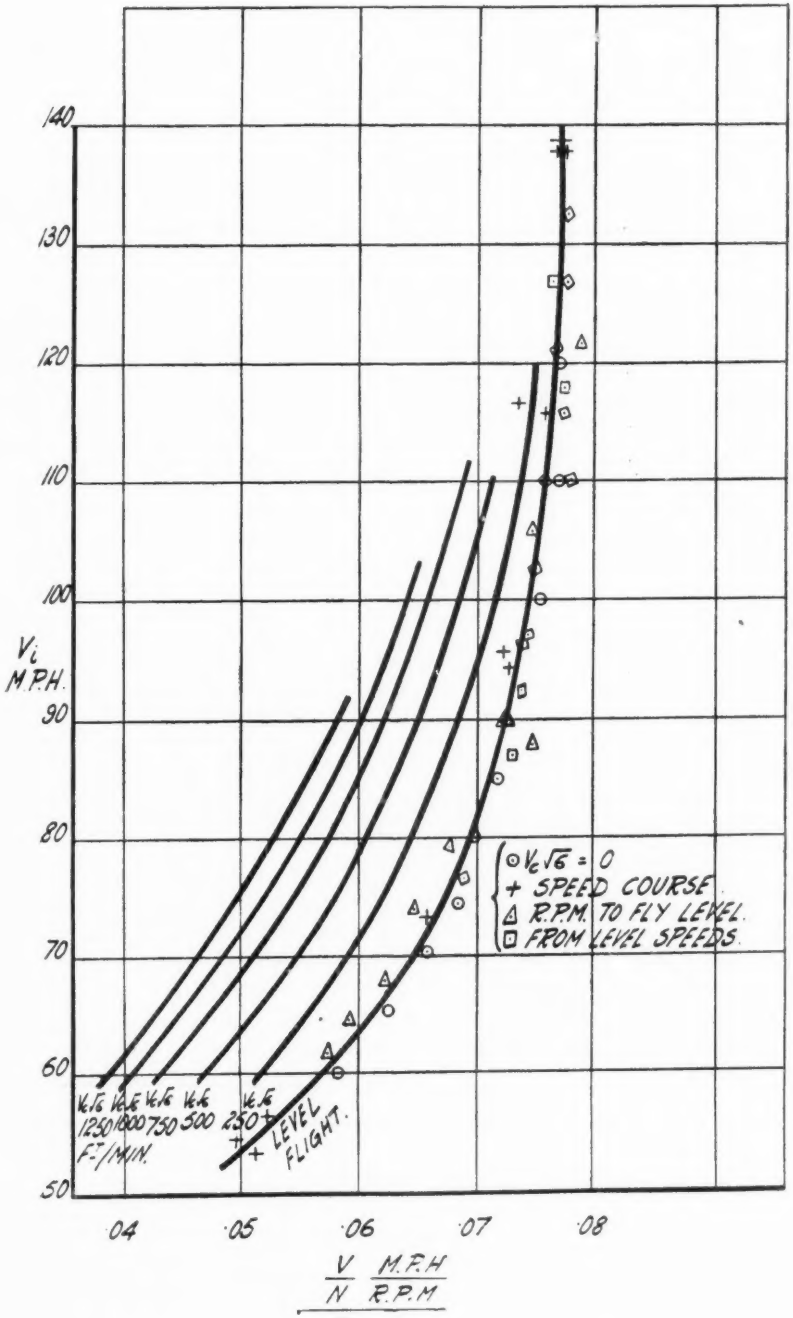

140
130
120
110
100
90
80
70
60
50
V_i M.P.H.
$V_c\sqrt{6}$ 1250
$V_c\sqrt{6}$ 1000
$V_c\sqrt{6}$ 750
$V_c\sqrt{6}$ 500
$V_c\sqrt{6}$ 250
FT./MIN.
LEVEL FLIGHT.
$V_c\sqrt{6} = 0$
SPEED COURSE.
R.P.M. TO FLY LEVEL.
FROM LEVEL SPEEDS.
·04
·05
·06
·07
·08
$\frac{V}{N}$ $\frac{M.P.H}{R.P.M}$

FIG. 8.

sequently, if from the partials is plotted a series of curves of $Vc\sqrt{\sigma}$ at constant $V\sqrt{\sigma}$ against V/N, a picture will be obtained which is independent of engine performance as a variation in throttle setting or engine power will merely move a point along one of the curves. A change in the aeroplane or airscrew or an up or down current in the atmosphere will move the point off its curve however.

Under similar assumptions, at a given "dynamic speed" the ratio of the forward speed to the r.p.m. at which the airscrew is driven is dependent on engine torque which on full throttle is a function of height.

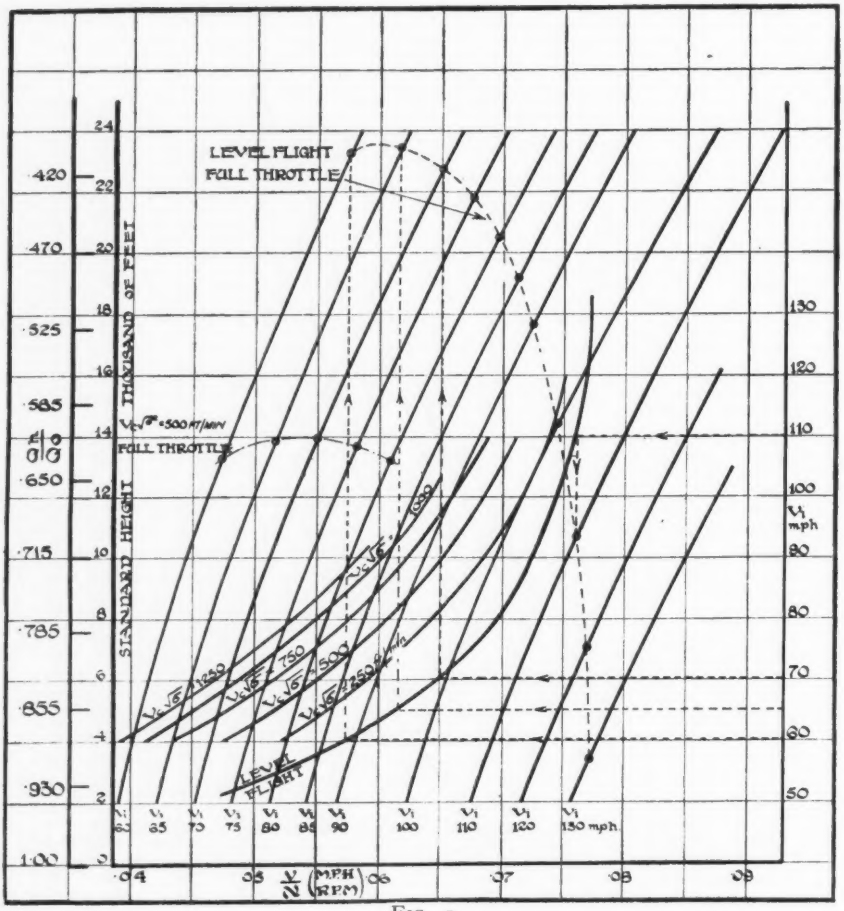


FIG. 9.

Therefore a further series of curves is drawn, of height against V/N again for constant values of the dynamic speed. These curves are practically unaffected by changes in the aeroplane or by up and down currents, but changes in engine or airscrew will throw the corresponding points off the curves.

Thus, if the points from a given test appear wrong on the first figure, but right on the second, up or down currents have been encountered or somebody

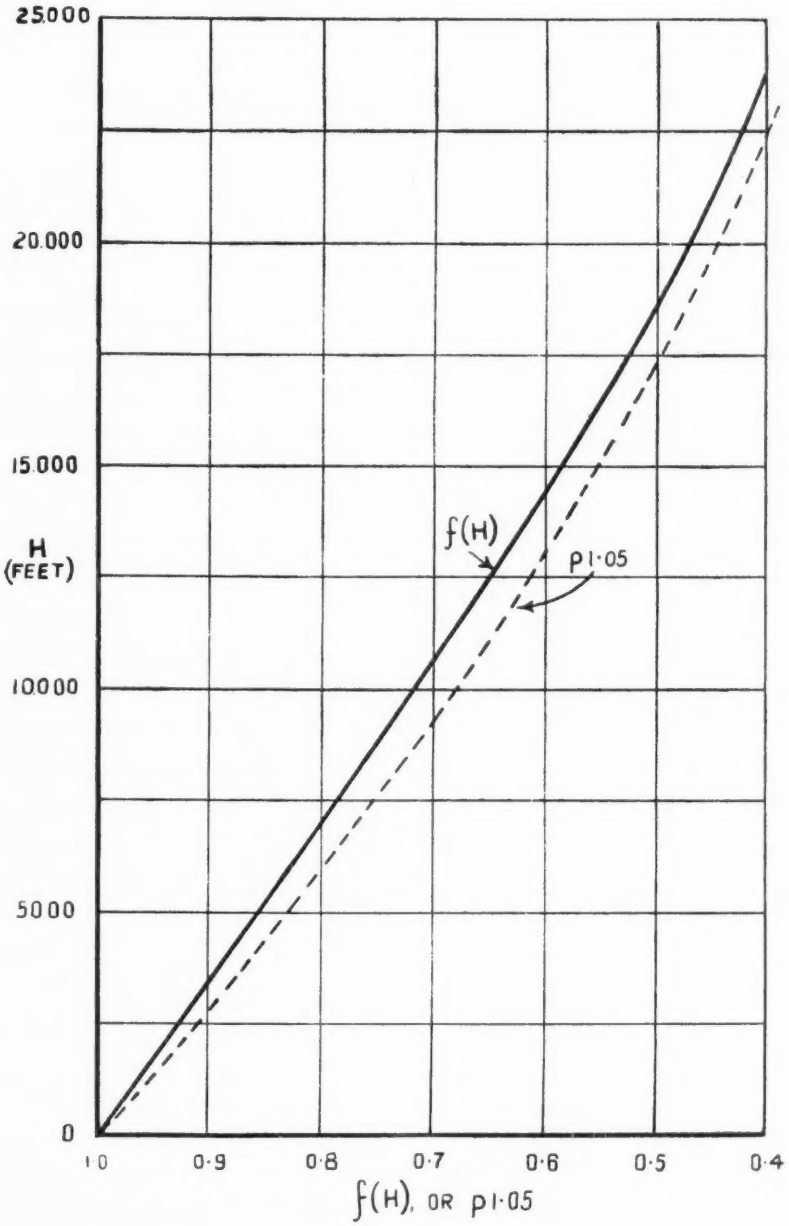

25000
20000
15000
H
(FEET)
10000
5000
0
1·0
0·9
0·8
0·7
0·6
0·5
0·4
f(H)
p1·05
f(H), OR p1·05

FIG. 10.

has tied something on the aeroplane when the Technical Office was not looking. If the points appear right on the first figure but wrong on the second, the engine is probably the trouble. While if they are wrong on both it is either the airscrew or several things at once.

The curves of $Vc\sqrt{\sigma}$ against V/N can be plotted another way round, *i.e.*, as curves of constant values of $Vc\sqrt{\sigma}$ in which $V\sqrt{\sigma}$ is plotted against V/N. The most interesting of these curves is that for $Vc\sqrt{\sigma}=0$, as this curve enables the level speed at height to be determined.

We now combine the last two pictures into one, which gives us a picture of the whole performance of the aeroplane. From it we can read off the maximum level speed at all heights, the maximum rate of climb and the best climbing speed, and the amount the aeroplane is throttled to fly level at any speed.

The picture which was dependent on engine power can be used to deduce the variation of engine power with height, or the ratio of engine torque at a given height to the torque at the same r.p.m. under ground conditions. The

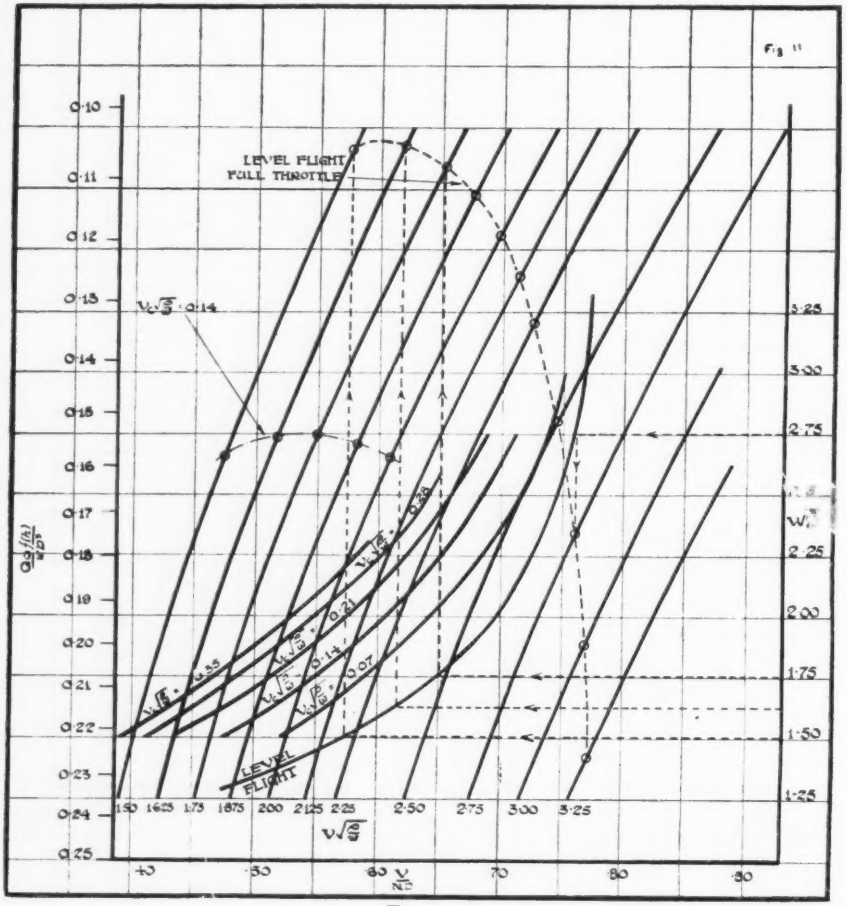


FIG. 11.

value of Q/Q_0 as mentioned above is usually $=p^{1.05}$ where p is the ratio of the pressure at any height to the ground pressure.

Having deduced this final piece of information the whole diagram may be made non-dimensional and used to deduce the performance of the aircraft at other weights than those of the test. V/N is already a non-dimensional in weight and we replace $Vc\sqrt{\sigma}$ by $Vc\sqrt{(\sigma/w)}$ and $V\sqrt{\sigma}$ by $V\sqrt{(\sigma/w)}$ where w is the loading. Alongside the height scale we put a scale of Qw_0/Q_0w where w_0 is the loading of the tests. Hence we can read off the value of Q/Q_0 w_0/w required for any condition of flight knowing w_0/w we can calculate Q/Q_0 and from the variation of power with height find the height at which the required performance is obtained.

This completes the most important of the correction work. The other tests carried out, landing and take-off runs, stalling speeds, stability tests, consumption tests, spinning and diving do not require much reduction. The preliminary weighing of the aircraft and making it up to requirements is a long job, but hardly needs explanation.

In conclusion, I should pay full appreciation to my predecessors, Colonel Tizard, Major Barlow and Mr. Capon, who have built up and perfected the organisation which enables all these tests to be gone through expeditiously and accurately.

Finally I take full responsibility for all statements made and opinions expressed in this lecture.

Discussion

At the conclusion of this paper Captain Keep, M.C. (who was in the chair), invited questions, and himself opened the discussion by asking how it was that there was such a big change in the results so as to make them unreliable when the tip-speed of the propeller was approximately the same as that of sound at great altitude.

The Lecturer replied that it was rather difficult to explain in a few words why this change takes place, but he understood that in some tests carried out at Farnborough, it was found that the propeller efficiency at this speed is reduced from something like 70 per cent. to 40 per cent. It is due to the fact that at these speeds air no longer behaves as an incompressible fluid, the flow round the blade sections changes and the characteristics of the airscrew change accordingly.

Mr. Gould then asked the Lecturer whether he understood him aright when he said they should correct for variations in the weight carried, and presumably this would only apply to loads carried internally.

Mr. Stevens replied that this was so.

Mr. Gould then asked how they allowed, therefore, for the difference in weight of torpedo-carrying machines with and without torpedo.

Mr. Stevens replied that the curves do not allow for this, but they have found by actual practice that the difference in speed was about two miles per hour. He also mentioned in this respect that the reduction in speed of a machine at 150 miles per hour, when the gunner stands up in the rear cockpit, is approximately four miles per hour.

Mr. Davenport asked whether the length of static head pipe line (40 to 70ft.), mentioned by the Lecturer, had been found to be necessary.

The Lecturer replied yes, they found with 20ft. there was probably one to one and half miles per hour difference, and that 40ft. was therefore the safe minimum for a small machine and 70ft. for a large machine. He explained that a suspended air log, comprising a streamline body at the end of a cable, carrying in the body an electric device driven by a small windmill in such a way that electric impulses were transmitted to the cockpit, so working a counter which gave the actual speed of the machine, would be fitted in the near future to replace the suspended static head.

Mr. TAYLOR asked what distance a machine had to fall in order to attain its terminal velocity of 250 to 290 miles per hour?

Mr. STEVENS replied the height drop allowed in tests was 5,000 to 7,000 feet.

Mr. BECK asked for a further explanation as to the changes in barometric pressure which have to be allowed for in the instruments and how these are affected by temperature.

Mr. STEVENS replied that seasonal changes in barometric reading are more a matter of the effect of turbulences in the air strata causing a change in the weight of a column of air, due to its effective height being displaced from normal by wave motion.

Mr. GIBSON asked how tests of stability were carried out.

Mr. STEVENS explained that a machine is flown at, say, 20 per cent. above the stalling speed and trimmed to fly, and then the stick is left free to see whether the machine rights itself. Similarly, the machine is trimmed to fly slightly downwards, and the controls left free to see whether the machine tends to continue on that flight path or take a nose dive. Again the rudder is set over, and the rudder bar left free to see if the machine resumes its normal attitude; whilst finally, for lateral control, the machine is put on a bank, and after freeing the controls, the time is noted in each case if the machine resumes its normal attitude or if the machine tends to hunt, or shows other signs of instability, the pilot making a careful note of the details regarding amplitude and time.

Mr. DAVIS asked what force could be put on aeroplane controls?

Mr. STEVENS replied that this was entirely a question of man power and thought, roughly speaking, a man would be able to pull 250 lbs. on the pilot's stick; 50 to 70 lbs. lateral force; whilst probably he could push 150 lbs with one leg.

Mr. DIGBY asked what the Lecturer considered was the desirable force to which controls should be designed to operate?

Mr. STEVENS said that he, personally, preferred light controls, and that probably something like 10 lbs. for the ailerons and rudder, and 5 lbs. for elevators would be suitable figures for single-seaters.

Mr. DAVIS then asked whether it was true that trouble had been experienced, due to the freezing up of greases on the controls at high altitude, and whether they had found gun oil suitable instead of grease?

The LECTURER replied that this was so, and when gun oil was used the controls worked satisfactorily.

Mr. METTAM, proposing a vote of thanks to the lecturer, remarked that he considered Mr. Stevens both his enemy and his friend. His enemy because of the alterations which always seemed to take place in the performance figures; but his friend inasmuch as, under his control at Martlesham, very careful detail tests were carried out, and some very useful data was thereby made available for the prediction of aeroplane performance. He thought the explanations given by the lecturer had made this involved subject of aeroplane performance testing much clearer than they had previously been expressed in papers on this subject.

SUMMARIES OF TECHNICAL PAPERS RECEIVED

(PREPARED BY THE EDITOR)

Aerodynamics

Preliminary Investigation on Boundary Layer Control by means of Suction and Pressure with the U.S.A. 27 Airfoil. F. G. Reid and M. J. Bamber. N.A.C.A. Technical Note No. 286. Washington, May, 1928.

SUMMARY.

Tests were made on a U.S.A.27 airfoil with various slot shapes and combinations, and at various amounts of pressure or suction on the slots.

The lift of airfoils can be increased by removing or by accelerating the boundary layer.

Removing the boundary layer by suction is more economical than to accelerate it by jet action. Gauze-covered suction slots apparently give the best results. When not in operation, all suction slots tested had a detrimental effect upon the aerodynamic characteristics of the airfoil which was not apparent with the backward opening pressure slots.

Thick blunt-nosed airfoils would seem to give the best results with boundary layer control.

The Connection between Lift and Circulation for an Inclined Flat Plate. A. Fage, A.R.C.Sc., and F. C. Johansen, B.Sc. R. & M. No. 1139 (Ae. 308). H.M.S.O., January, 1928.

SUMMARY.

It is shown that the Kutta-Joukowski relationship between lift and circulation holds very closely for an inclined flat plate in an air stream, provided that the contour around which the circulation is taken is large and that it cuts the wake in a straight line perpendicular to the direction of the undisturbed motion. Also the total strength of the vorticity at the front of the plate can be determined from observations of pressure on the plate.

The Structure of Vortex Sheets. A. Fage, A.R.C.Sc., and F. C. Johansen, B.Sc. R. & M. No. 1143 (Ae. 311). H.M.S.O., August, 1927.

SUMMARY.

The structure of the sheets shed from infinitely long bodies of widely different cross section has been examined. Measurements have also been made to determine the principal characteristics of the vortex sheets formed at some distance behind each body.

It is established from estimations of vorticity and also from observations of total head, that the outer boundary of a sheet can be taken as a line drawn through the points in the field of maximum velocity (V_1), and the inner boundary as the line passing through the points of minimum velocity (V_2). The motion in a sheet is steady near the body, except possibly near the inner boundary.

The pressure at points in an outer boundary is slightly greater than that in the dead air region behind the body.

Air flows into a sheet through both boundaries, but at a greater rate through the outer boundary. The simple expression $(V_1^2 - V_2^2)/2V_0^2$ gives a close estimate of the total amount of vorticity passing a section of a sheet in unit time.

Vorticity is shed from the two sides of an asymmetric body at the same rate.

The variation of velocity across a section of a sheet, and also the rate of increase of the breadth with the distance downstream, depend on the form of the body. The velocity distribution in the sheet shed from a flat plate normal to the stream is in close agreement with that predicted by the Prandtl-Tollmien theory.

At constant forward speed, both the frequency and the longitudinal spacing of the individual vortices in the vortex street depend largely on the lateral spacing between the sheets, and to a smaller extent on the form of the body.

On the Flow of a Compressible Fluid Past an Obstacle. Dr. H. Lamb, F.R.S. R. & M. No. 1156 (Ae. 321). H.M.S.O., April, 1928.

SUMMARY.

An extension of the flow past a cylinder without circulation of the fluid round it, discussed originally by Rayleigh, to include circulation.

Aerofoils

Wind Tunnel Tests on Aerofoil R.A.F. 36. F. B. Bradfield and K. W. Clark, B.Sc., D.I.C. R. & M. No. 1147 (Ae. 315), December, 1927.

SUMMARY.

Lift, drag and centre of pressure have been determined at $R = 0.251 \times 10^6$ and 0.336×10^6, and minimum drag was measured from $R = 0.168 \times 10^6$ to $R = 1.00 \times 10^6$. The main characteristics at $R = 0.251 \times 10^6$ are given, compared with other aerofoils in the series.

Scale Effect on Three Aerofoils at Low Values of LV, R.A.F. 32, Göttingen 433 and Göttingen 410, with 2 per cent. Centre Line Camber. F. B. Bradfield. R. & M. No. 1117 (Ae. 290). H.M.S.O., August, 1927.

SUMMARY.

Lift and drag were measured down to $LV = 2\frac{1}{2}$. Minimum drag at $LV = 2\frac{1}{2}$ is about 0.025 for R.A.F. 32 section or for Göttingen 410 (cambered), and about 0.04 for Göttingen 433. As the scale decreases the no-lift angle occurs at a more and more positive incidence, the slope of the lift curve remaining roughly constant. In the case of Göttingen 433 and Göttingen 410 (cambered), the ordinary stall has disappeared from the lift curves at the lowest LV's tested, the lift decreasing gradually over a 40° incidence range.

Aerodynamic Characteristics of Aerofoils—V. N.A.C.A. Report No. 286. Washington, 1928.

SUMMARY.

Continuation of Reports Nos. 93, 124, 182 and 244.

This collection of data on aerofoils has been made from the published reports of a number of the leading aerodynamical laboratories of the United States and Europe, and is presented in a uniform series of charts and tables suitable for the use of designing engineers and for general reference.

Wind Tunnel Tests on a R.A.F. 15 Aerofoil with Pilot Planes. F. B. Bradfield and K. W. Clark, B.Sc., D.I.C. R. & M. No. 1145 (Ae. 313). October, 1927. H.M.S.O.

SUMMARY.

A pilot plane is an auxiliary aerofoil pivoted ahead of a wing so as to provide automatically a slotted wing at high incidence without much increase of drag at fine angles. The maximum lift region was investigated with pilot planes of

chord 7½ per cent., 10 per cent. and 12½ per cent. of the main chord, trying different hinge positions relative to the main wing in each case. The drag of the best lift arrangement for each pilot plane was measured, and the angle at which the pilot plane floated freely was recorded.

With a 10 per cent. pilot plane, the maximum lift coefficient of a R.A.F. 15 aerofoil may be increased to 0.80, and the increase of drag at top speed is less than the minimum drag of the pilot plane when tested alone; but the increase of drag is greater on the climb. By making the stop which limits the pilot plane angle vary with the aileron angle, the pilot plane gives an efficient slot-and-aileron control, the pilot plane reversing the sign of the yawing moments at angles just over the stall. With fixed stop the aileron control is much improved by fitting pilot planes, but the effective control may still be poor owing to the pilot plane increasing the stability.

Aeronautics—General

Flying. Lieut.-Colonel W. Lockwood Marsh, M.A. May, 1928.

SUMMARY.

One of a series in the modern pictorial library. A short general account, extensively illustrated, of aeroplanes, seaplanes and airships.

Aeroplanes—General

Elements of Aviation. V. E. Clark. Ronald Press Company. 1928.

CHAPTER HEADINGS.

The Air and the Airfoil; Airfoils and Airflow; Effects of Airflow; Stability and Control; Propeller Effects; Accelerated Flight; The Earth's Atmosphere and the Effects of Altitude; Parts of an Airplane; Weights and Dimensions.

Aeroplanes—Full Scale Experiments

Full-Scale and Model Measurements of Lift and Drag of a Bristol Fighter fitted with R.A.F. 34 Wings. J. K. Hardy, B.A., and A. S. Hartshorn, B.Sc. R. & M. No. 1146 (Ae. 314). November, 1927. H.M.S.O.

SUMMARY.

The report forms one of a series describing comparisons between the full-scale and model lift and drag of biplanes fitted with thick wings. The lift and drag of a Bristol Fighter with wings of R.A.F. 34 section have been determined for the full-scale aeroplane and for a 1/10th scale at speeds of 40, 60 and 80 ft./sec.

The maximum lift coefficient (0.56) is higher for the full-scale aeroplane than for the model (0.52), but the increase is not so great as for R.A.F. 30 or R.A.F. 31. The minimum drag coefficients, both model and full-scale, are the same as for R.A.F. 31, which has the same centre line camber and thickness, but is not reflexed.

Aeroplanes—Performance

Notes on Performance Testing. H. L. Stevens, B.A., and A. E. Woodward Nutt, B.A. R. & M. No. 1140 (Ae. 309). February, 1928. H.M.S.O.

SUMMARY.

Describes methods of performance testing and analysis at present in use at Martlesham Heath. The straightforward method of direct measurement of climbs and speeds and the research method of Mr. Capon are discussed. The present method is a combination of both.

Airships

The Resistance of the International Airship Models Measured in the Wind Tunnel of the Royal College of Science, South Kensington, S.W.7. Professor F. T. Hill and G. Tanner, A.C.G.I., D.I.C. H.M.S.O., March, 1928.

SUMMARY.

Tables of results are given. These are the models already tested in the wind tunnels in America, Japan, Italy, France, the R.A.E. and the N.P.L.

Airscrews

Tests of a Metal Airscrew in a Closed Tunnel for Comparison with American Tests in an Open Jet Tunnel. H. C. H. Townend, B.Sc., and J. H. Warsop. R. & M. No. 1137 (Ae. 307). H.M.S.O., December, 1927.

SUMMARY.

Results of tests are shown in figures and tables. Tests were carried out in 7ft. closed tunnel. Comparison with the American results shows excellent agreement on thrust over the entire range, while the torque is slightly higher, so that the maximum efficiency is about $1\frac{1}{2}$ per cent. lower than that obtained in the American test. The screw tested was a 3ft. diameter two-bladed metal airscrew of medium pitch.

Autogyro

Further Development of Autogyro Theory. Parts I. and II. C. N. H. Lock, M.A. R. & M. No. 1,127 (Ae. 209). March, 1927. H.M.S.O.

SUMMARY.

The object of the present R. & M. is to develop the theory of the autogyro and remove some of the approximations of R. & M. No. 1111.

After working out the force components, an alternative method of determining the drag is developed, based on considerations of energy loss; it has been verified that the resulting formulæ give results identical with those already obtained, and, being more simple, take the place of the rather complicated formulæ for the longitudinal force.

The ratio of the value of maximum lift/drag of the present investigations (the true value for heavy blades subject to the assumptions that the coefficient of axial velocity through the disc is constant over the disc and is a small quantity; and the lift coefficient of a blade element is proportional to the incidence, and the profile drag coefficient is constant) to the values given in R. & M. No. 1111 is as follows:—

Blade angle	0°	2°	4°
Ratio	1.025	1.44	2.1

On account of the errors introduced by the assumptions the actual value of lift/drag is probably lower than obtained here, and may in fact be closer to the value obtained in R. & M. No. 1111.

Bombs and Ballistics

The Experimental Determination of the Trajectory of Aircraft Bombs. H. E. Wimperis, C.B.E., M.A. R. & M. No. 1,121 (Ae. 294). June, 1928. H.M.S.O.

SUMMARY.

Full scale experiments were made at various air stations and use was made of a coal mine shaft in Yorkshire. It was found that the particle trajectory was sufficiently closely followed for the practical purposes of the moment, and a tech-

nique of bomb sighting was built thereon. This led to the introduction into the Air Forces of Great Britain of the system of sighting described. A full scale study was also made of the under-water trajectory of a bomb above the sea; this was required for the purposes of the anti-submarine aircraft patrol.

Dopes

Researches on Cellulose Acetate and its Solution. Composition of Cellulose Acetate Lacquer for Aeroplane Dope. K. Atsuki, and R. Shinoda, Y. Tanaka.

II. Stability of Cellulose Acetate.
III. Stabiliser for Cellulose Acetate.
IV. On the Acetylation of Cellulose.
V. Relation of Temperature and Time of Ripening to the Viscosity of Cellulose Acetate.

Reports of the A.R.I., Tokyo Imperial University, Nos. 32-36. February-March, 1928.

SUMMARIES.

I. The optimum composition of the mixed solvent for cellulose acetate in the preparation of an aeroplane dope was studied by determining the solvent power of the mixed solvent, the viscosity of the cellulose acetate solution in the mixed solvent, and the tensile strength and elongation of the film produced. It is proved that the composition of the mixed solvent, which has the highest solvent power and gives the lowest viscosity of cellulose acetate solution, produces a film of the highest tensile strength and elongation.

Using the most common solvents, the optimum composition of the mixed solvent is acetone 60 per cent., ethyl alcohol 15-17 per cent., benzene 19-21 per cent., benzyl alcohol 1-2 per cent., and triphenyl phosphate 1-2 per cent., and the optimum concentration of cellulose acetate is 7-9 per cent.

II. The spontaneous decomposition of cellulose acetate, prepared by using sulphuric acid as a catalyst, is governed by the sulphuric acid, which is present as a free state or as an adsorption compound or as the ester of cellulose. The amount of the sulphuric acid retained decreases as the ripening of cellulose acetate proceeds, because of the saponification of the sulphuric ester, and because of the coagulating power becoming weak, making the diffusion of acid easy. The decomposition products of cellulose by oxidation and hydrolysis have no direct concern with the stability.

III. Calcium naphthenate is found to be the most effective stabiliser for cellulose acetate as well as for cellulose nitrate. The amount of calcium naphthenate to be added must be calculated from the amount of the sulphuric acid present, but in general cases 1-2 per cent. on cellulose acetate will be sufficient.

IV. In an excessive acetylation, the cellulose transforms successively as peptisation—acetylation—acetolysis—equilibrium. Cellibiose and glucose, the end products of the acetolysis, are not formed at the beginning of the acetylation. The reactions involved in the acetylation are not clearly known. The authors have carried out experiments for the object of studying the modification and acetylation of cellulose in general.

V. The viscosity may be used as the indicator for measuring the degree of the ripening of cellulose acetate, and it is governed by the temperature and time of the ripening, if the other conditions are kept constant. The relation between the temperature and time of the ripening to produce a cellulose acetate of a given viscosity was experimented upon, and from the result of the experiment as well as from the theoretical calculation, the expression $T = ae^{kz}$ was obtained for a given viscosity, in which T is the temperature and z is the time of ripening, and a and k are contents.

Engines

Motoring Losses in Internal Combustion Engines. H. Moss, D.Sc., A.R.C.S., D.I.C. R. & M. No. 1128 (E. 27). H.M.S.O., July, 1927.

SUMMARY.

The total frictional losses of a Benz single cylinder engine were found when motored at speeds of 1,200 r.p.m. and 900 r.p.m. with air densities ranging from normal to twice normal. The pumping losses, measured by an R.A.E. electrical indicator, were deducted, the remainder being the sliding friction of engine and accessories.

The sliding friction under power may be greater than when motoring by the equivalent of 3.5 lbs. per sq. in. M.E.P. due to this cause. With an increase of 3.5 lbs./sq. in. M.E.P., found by Ricardo due to carbonisation, the magnitude of the effect when running under power with a normal spark setting is fully explained.

The Determination of the Horse-Power Height Factor of Engines from the Results of Type Trials of Aircraft. J. D. Coales and A. L. Lingard. R. & M. No. 1141 (Ae. 310). H.M.S.O., October, 1927.

SUMMARY.

The average values of the power factor have been determined for heights in a standard atmosphere from the type trial reports of a large number of aircraft. The method of obtaining the power factors of an engine in a standard atmosphere appears to yield reasonable values for this factor; but it gives no clue as to the dependence of the factor upon pressure or density respectively. This is because temperature, pressure and density in a standard atmosphere can each be expressed as definite functions of either one or both of the others.

Engines—Supercharging

A Preliminary Investigation of Supercharging an Air-Cooled Engine in Flight. Marsden Ware and Oscar W. Schey. N.A.C.A. Report No. 283. Washington, 1928.

SUMMARY.

Service training aeroplanes were used, equipped with production types of Wright engines. An N.A.C.A. Roots' type supercharger was driven from the rear of the engine. In addition to measuring those quantities that would enable the determination of the climb performance, measurements were made of the cylinder head temperatures and the carburettor pressures and temperatures. The supercharging equipment was not removed from the aeroplane when making flights without supercharging, but a by-pass valve, which controlled the amount of supercharging by returning to the atmosphere the surplus air delivered by the supercharger, was left full open.

With the supercharger so geared that the ground level pressure could be maintained to 18,500 feet, it was found that the absolute ceiling was increased from 19,400 to 32,000 feet, that the time to climb to 16,000 feet was decreased from 32 to 16 minutes, and that this amount of supercharging apparently did not injure the engine.

The Comparative Performance of Roots' Type Aircraft Engine Superchargers as Affected by Change in Impeller Speed and Displacement. Marsden Ware and E. E. Wilson. N.A.C.A. Report No. 284. Washington, 1928.

SUMMARY.

Results of tests on three sizes of Roots' type aircraft engine superchargers. From the tests it is evident that impeller speed and displacement have an

appreciable effect on the performance characteristics of Roots' superchargers aside from their effect as a result of a direct proportional relation. It may be concluded, however, that the speed of impeller operation may be increased to at least 6,000 r.p.m. without imposing any serious performance limitation—the volumetric efficiency is not seriously reduced and the power required per pound of air delivered is not increased excessively at this speed. The results obtained with the 4-inch supercharger indicate that good performance characteristics may be obtained with this relatively small machine, which lends itself to a compact type of construction so much desired in aircraft practice.

Fluid Motion

Some Experiments on Motion of Fluids. Part IV. T. Terada and K. Hattori. Report of the A.R.I., Tokyo Imperial University. August, 1927.

SUMMARY.

From the experimental results it may be seen that the formation of the regularly periodic columnar vortices around a rotating cylinder, as was studied by G. I. Taylor, may be regarded as a special case of a wide class of vortical motions caused by rotation of body in liquid at large.

Fuels—Detonation

Lower Limit of Inflammability of Ethyl Alcohol, Ethyl Ether, Methyl Cyclohexane and their Mixtures. Y. Tanaka, Y. Nagai and K. Akiyama. Report of the A.R.I., Tokyo Imperial University, No. 21. March, 1927.

SUMMARY.

The authors describe the results of their research on the lower limits of inflammability of the above. The results showed that the lower limit of inflammability of ethyl alcohol, ethyl ether and methyl cyclohexane for open firing are 3.81 per cent., 1.93 per cent. and 1.15 per cent. respectively, and that the theoretical flame propagation temperatures of methyl cyclohexane are nearly the same as those of paraffin hydrocarbons, showing that the naphthene ring has no effect on the theoretical flame propagation temperatures of hydrocarbons. It was also shown that in all mixtures examined, Le Chatelier's rule holds well, the deviation being of much the same order as the experimental error.

Helicopters

On the Horizontal Flight of a Helicopter. H. Glauert, M.A. R. & M. No. 1,157 (Ae. 322). H.M.S.O., March, 1928.

SUMMARY.

In a previous report (R. & M. No. 1132) a theory has been developed for the vertical ascent of a helicopter. The analysis has now been extended to cover the case of horizontal flight also. The analysis is confined to the case when the helicopter is in horizontal flight with its axis vertical. The effect of variation of the blade angle is considered and also the effect of the periodic motion on the behaviour of airscrews mounted on the blades. The effect of the horizontal motion is to reduce the power required for sustentation. The drag force is not high and the helicopter should therefore be able to attain a satisfactory horizontal speed.

Hydrogen

Studies on the Inflammability of Hydrogen. Parts I.-IV. Y. Tanaka and Y. Nagai. Report of the A.R.I., Tokyo Imperial University. April, 1927—May, 1927. No. 22.

SUMMARY.

The reports deal with the influences of ethyl bromide, organic bromine and iodine compounds, di-ethyl selenide and hydrogen selenide on the limits of inflammability of hydrogen air mixtures.

Instruments

Report on the Development of a Hot-Wire Rate of Descent Meter. G. W. H. Gardner, B.Sc., and F. W. Meredith, B.A. R. & M. No. 1,144 (Ae. 312). H.M.S.O., 1928.

SUMMARY.

The purpose of the investigation was to provide an instrument for aerodynamic research which would indicate varying rates of descent of an aeroplane with an accuracy of $\pm$1ft. per second.

The instrument developed will indicate the rate of descent of an aeroplane within a range of o-6oft. per second with an accuracy of $\pm$1ft. per second and has an indication time-lag to $1/e$ of its amplitude of less than one second. The instrument is bulky and is not recommended for other purposes than aerodynamic research. At the request of the Aeronautical Research Committee a rate of descent recorder involving the principle of the existing hot-wire rate of descent indicator is now being designed.

Instruments—Air Flow

Measurement of Variable Velocity Relative to Air with Pitot Static Tubes. K. Wada and S. Nisikawa. Report of the A.R.I., Tokyo Imperial University, No. 27. November, 1927.

SUMMARY

Among others the following are discussed in the paper:—(1) Relation between the velocity of a pitot static tube and its pressure indication when the latter was not constant in time. (2) Influence of the friction between the air and the solid wall of the pipe, which connects a pitot static tube to a manometer on the propagation of pressure through it. (3) Relation between the volume capacity of the pressure chamber of a manometer and the pressure indicated.

Materials—General

Researches on Springs. 3, *Torsional Fatigue Tests on Spring Steels.* H.M.S.O., 1928.

SUMMARY.

In general, the values of the safe ranges for reversed and repeated stresses are roughly proportional to the tensile strength of the various materials; the ratios of the safe ranges for reversed stresses to the ultimate tensile strengths are about the same as those obtained for normalised steels in the Stromeyer machine.

For the hardened and tempered spring steels the chrome vanadium is slightly superior to the 0.6 per cent. carbon steel, although the tensile strengths are the same. The silico manganese steel, although of greater tensile strength than the chrome vanadium steel, does not give higher safe ranges. Apparently, the values of the safe ranges for repeated stresses are higher than those usually

obtained from actual springs in service, but the present tests were carried out on carefully prepared specimens in which all surface defects had been reduced to a minimum.

In the case of hardened and tempered spring steels, there are marked decreases in the safe ranges at the high mean stresses, but the results are still considerably above the modified Goodman values.

Stresses in a Plate Bounded by a Hyperbolic Cylinder. A. A. Griffith, D.Eng. R. & M. No. 1152 (M. 55). H.M.S.O. January, 1928.

SUMMARY.

The problem is attacked by the method of finding solutions for the case of a plate bounded by a hyperbolic cylinder, which in the limit gives a representation of a solid containing two long cracks which nearly meet. Two solutions are obtained (1) for the case of a shearing load and (2) for the case of a tensile load.

The theory indicates that in a solid containing cracks of the type described, certain elements can undergo elastic rotations of the order of 5° to 20°. In the case of crystals this inference suggests a possible experimental means of establishing the existence of such cracks or their equivalents.

Materials—Duralumin

Corrosion Embrittlement of Duralumin. I. Practical aspects of the problem. II. Accelerated corrosion tests and the behaviour of high strength aluminium alloys of different compositions. III. Effect of the previous treatment of sheet material on the susceptibility to this type of corrosion. IV. The use of protective coatings. Henry S. Rawdon. N.A.C.A. Technical Notes Nos. 282-285. Washington, April, 1928.

SUMMARY.

PART I.

Duralumin referred to in these papers is taken as referring to the class of heat-treatable alloys containing Cu, Mg, Mn and Si, and not to the product of any particular manufacturer. It can be positively stated that embrittlement results from sources outside the duralumin and is not spontaneous disintegration of the material itself. The danger from embrittlement decreases as the cross section of the duralumin increases. The purpose of these reports is to develop methods of improvement and protection which would ensure the reliability and permanence of duralumin.

PART II.

Corrosion of aluminium alloys of the duralumin type shows itself either as a roughening (pitting) of the surface or a penetration into the body of the metal, the path by which it progresses invariably being an intercrystalline one. In the second case the external appearance gives no true indication of the change which has taken place and the breaking load may become very small. The ordinary loss-of-weight corrosion tests are useless in the second case. Experiments were carried out to obtain the intercrystalline effects under conditions representative of those obtaining in aircraft in service. Chloride solutions and halogen solutions caused the intercrystalline effects, but nitrates, sulphates and carbonates had no appreciable corrosive effect and caused no intercrystalline attack.

Of the alloying elements copper appears to be most closely associated with the propensity of the material towards intercrystalline corrosion. The method of heat treatment is important. With certain solutions the corrosion rate is rapidly increased with increase of temperature.

X-ray examinations by the pin-hole method do not afford a sure means for distinguishing sheet duralumin which is very susceptible to intercrystalline corrosion from that which is not.

A good bibliography is attached to the paper.

PART III.

The results summarised in this report show conclusively that the tendency of sheet duralumin and the related high-strength aluminium alloys to corrode in an intercrystalline manner is intimately related to the method of heat treatment used for the material.

PART IV.

Protection of the surface is still necessary if long life under varied service conditions is to be ensured. On many points concerning the service behaviour of the coatings, information which can be gained only from the weather exposure tests now under way is necessary before final conclusions can be drawn.

Coatings used may be conveniently grouped into three classes: The varied type of coatings, which are non-metallic in their nature and are applied by brushing, spraying, or dipping; the oxide type, produced by a chemical treatment of the metal whereby the surface metal is converted into a film of oxide or some similar compound; and metallic coatings, of which aluminium appears to be the most promising.

The newer coating methods which appear most promising on the basis of the evidence so far obtainable are (*a*) metallic aluminium; (*b*) oil or grease over the anodic coating (with frequent re-oiling for thin oil coats or with aluminium powder over heavy coats); (*c*) tight-clinging rubber cement carrying, or covered by, aluminium powder—do not readily crack, flake nor bare the duralumin beneath, on weathering and vibration, which is in marked contrast to the ordinary "aluminised" varnish or bitumastic coatings.

Materials, Steel

The Determination of the Elastic Moduli of a Mild and a Medium Steel: H. E. Smith, B.Sc., and H. L. Cox, B.A. R. & M. No. 1,138 (M. 53). H.M.S.O., June, 1927.

SUMMARY.

The general object of the research was to determine as accurately as possible the elastic contents of certain materials, particularly the standard research materials of the A.R.C. The authors measured E_1, σ_{12} and E_2; σ_{21} was then deduced from the equation $\sigma_{12}/E_1=\sigma_{21}/E_2$ and σ_{21} was also determined directly, and the two values compared. E_1 and σ_{12} were determined from the results of longitudinal and lateral displacement measurements on a circularly cylindrical solid specimen subjected to a simple tensile stress in the direction of the axis of the specimens. E_{12} was determined from the results of lateral displacement measurements on a similar hollow specimen subjected to internal pressure, the end stress due to this pressure being allowed to bear on the specimen. The symbols are:—

E_1 = Young's modulus in the direction of the z axis.
E_2 = Young's modulus in the transverse direction.
σ_{12} = Ratio of the transverse contraction to the longitudinal extension.
σ_{12} = Ratio of the longitudinal contraction to the transverse extension.

All the tests were tensile tests.

Medical

Experimental Study on the Effects of Low Barometric Pressures and Oxygen Deprivation upon the Efficiency of Mental and Physical Work. K. Tanaka. Report of the A.R.I., Tokyo Imperial University, No. 37. March, 1928.

CONTENTS.

The effects of changes of barometric pressures upon the efficiency of mental and physical work; the effects of changes of barometric pressures upon the muscular strength; the effects of changes of barometric pressures upon handwriting; the effects of changes of barometric pressures upon the reaction time; the effects of supplying oxygen.

Meteorology

Correlations of World Weather and a Formula for Forecasting the Height of the Parana River. E. W. Bliss, M.A., B.Sc., A.Inst.P., F.R.Met.Soc. February, 1928.

SUMMARY.

Continuing the study of world weather, the following three centres have been added to those previously examined, St. Vincent temperature, S. Rhodesia rainfall, and the height of the Parana river. A formula is obtained on which is based a forecast in September of the probable height of the river in November to May.

Some Studies in Terrestrial Radiation. G. C. Simpson, C.B., F.R.S., F.R.Met.Soc. Memoirs of the Royal Meteorological Society, Vol. II., No. 16. March, 1928.

SUMMARY.

It is assumed that water vapour is the only constituent of the atmosphere which absorbs and emits long wave radiation. From the results of the upper air observations approximate values of the temperature and water content of the atmosphere at all heights and in all latitudes are adopted. Knowing the amount of water vapour and the temperature, it is possible to calculate the outgoing radiation if the absorption coefficient of water vapour is known. As the outgoing radiation is practically independent of the temperature of the surface, the problem arises as to how the temperature of the atmosphere readjusts itself to changes in solar radiation. This problem is considered in detail, but no solution is found.

Further Studies in Terrestrial Radiation. G. C. Simpson, C.B., F.R.S., F.R. Met. Soc. Memoirs of the Royal Meteorological Society. Vol. III., No. 21. London, July, 1928.

SUMMARY.

By using the observed temperatures of the earth's surface and of the stratosphere, and observed values for the absorption coefficients for water vapour and carbon dioxide, approximate values have been obtained for the outgoing radiation from the earth and its atmosphere, and the laws governing nocturnal radiation have been indicated. Values have been found for the horizontal transfer of heat across the circles of latitude which is necessary to obtain radiative equilibrium of the atmosphere as a whole. The consequences of changes in the intensity of solar radiation have been investigated, and the conclusions drawn that change in cloud amount would be the chief agency by which radiative equilibrium would be restored. An increase in solar radiation would result in increased cloud and

precipitation, while a decrease in solar energy would lead to less cloud and less precipitation. The possibility of increased solar activity leading to an " ice age " is discussed.

Harmonic Analogies and the Interpretation of the Results of Periodogram Investigations. D. Brunt, M.A., B.Sc., F.R.Met.Soc. Memoirs of the Royal Meteorological Society, Vol. II., No. 15. March, 1928.

SUMMARY.

The paper collects together for convenience of reference the formulæ used in harmonic analogies.

On Errors in the Multiple Correlation Coefficient Due to Random Sampling. J. Wishart, M.A., B.Sc. Memoirs of the Royal Meteorological Society, Vol. II., No. 13. February, 1928.

SUMMARY.

The use of the multiple correlation coefficient in weather forecasting was suggested by Sir Gilbert Walker in 1910. The author has approached the problem experimentally. The experiment showed, and theory confirmed, that when there is no real multiple correlation between the factors studied, definite values for the mean of a large number of samples, and for the variance, occur. The form of the results for the more general case of real relationship existing between the factors is suggested, but the theory is still far from complete.

On the Mechanism of Cyclones and Anti-Cyclones. Part II. T. Kobayasi. Report of the A.R.I., Tokyo Imperial University, No. 20. March, 1927.

SUMMARY.

Gives examples of lines of discontinuity and boundaries of centripetal current drawn on weather charts; lines of discontinuity in anti-cyclones; the translational motion of cyclones and anti-cyclones.

The paper is a continuation of a previous paper with the same title.

Seaplanes

A Dangerous Seaplane Landing Condition. T. Carroll. N.A.C.A. Technical Note, No. 287. Washington, May, 1928.

SUMMARY.

A peculiar phenomenon in seaplane landing is observed and reported. The seaplane having executed a normal fast landing at low incidence a forward movement of the control stick effected an unusual condition in that the seaplane left the water suddenly in an abnormal attitude. The observations describing the phenomenon are offered as a warning against possible accident and as a conjectural cause of seaplane landing accidents of a certain kind.

The Reaction on a Float Bottom when Making Contact with Water at High Speeds. H. C. Richardson. N.A.C.A. Technical Note, No. 288. Washington, May, 1928.

SUMMARY.

Gives an explanation of the phenomenon observed in Technical Note No. 287, and adds: " I would like to emphasise the fact that it may be very dangerous to fly at low angles of attack and high speeds just above the surface of the water. In this position an accidental contact with the surface of the water may lead to a serious crash."

Wind Tunnels

The Effect of the Static Pressure Gradient on the Drag of a Body Tested in a Wind Tunnel. H. Glauert, M.A., F.R.Ae.S. R. & M. No. 1158 (Ae. 323). H.M.S.O., March, 1928.

SUMMARY.

A correction has usually been applied to the observed drag of a body tested in a wind tunnel to allow for the effect of the observed static pressure gradient on the hypothesis that the additional drag experienced by the body is equal to the product of the volume of the body and of the observed pressure gradient.

An attempt is made in this paper to establish the correction on a more rational basis.

The correction is shown to be proportional to the product of the pressure gradient and of a certain effective volume, which is in all the cases examined, greater than the volume of the body, and it is shown that there is such a correction even in the case of a flat plate normal to the wind. The conventional formula is possibly sufficiently accurate in most cases, but for high accuracy, when the correction is required to be in error by less than 20 per cent., the effective volume should be calculated by the method suggested in the report.

A Theoretical Estimate of the Pressure Gradient in a Wind Tunnel. H. Glauert, M.A., F.R.Ae.S. R. & M. No. 1159 (Ae. 324). H.M.S.O., April, 1928.

SUMMARY.

The pressure gradient which is known to occur in wind tunnels of the N.P.L. type gives rise to an additional drag force on a model above that which would occur in a uniform stream.

A theoretical expression has been obtained for the pressure gradient due to the development of a boundary layer of retarded air along the walls of a wind tunnel, and as the value so obtained was less than that observed, the analysis has been extended to examine the effect of any leaks in the tunnel walls. A satisfactory explanation of the observed values is then obtained.

The observed pressure gradient depends only in part on the development of the boundary layer, and subsidiary causes, such as leaks in the tunnel walls, may be equally important. It is important, therefore, to avoid any leaks near the working section of a wind tunnel when testing a model whose drag is susceptible to the pressure gradient.

Variable Density Wind Tunnel. Report of the Scale Effect Panel. R. & M. No. 1,149 (Ae. 316). H.M.S.O., 1928.

SUMMARY.

The Panel is satisfied that the variable density wind tunnel has justified its place in the essential apparatus of a first-class aerodynamic laboratory. The provision of such a tunnel would enable a large amount of experimental work to be done in the laboratory which otherwise would only be conducted much more slowly and at a greater cost in free flight. The Panel is of the opinion that the tunnel should not be regarded as a means of reducing the present full scale facilities, but as a means of accelerating and extending aerodynamic research. So far as can be seen, full scale experiments must remain the ultimate standard of reference. It is expected that the value of the variable density tunnel will be found chiefly in effecting a reduction of landing speeds, investigating control at low speeds, and improving performance by the reduction of drag. The Panel strongly recommends the construction of a variable density wind tunnel in this country.

REVIEWS

" Engineering Aerodynamics "

By W. S. Diehl. Ronald Press, New York. $7.00.

This book, as the title indicates, is intended to help the aeronautical engineer who already possesses a good grounding in the physics of the subject. Its merit consists in that it collects the latest data, empirical formulæ and characteristics somewhat in the fashion of an engineer's pocket-book, and yet knits this rather dry material in a connected and readable form. The data are compiled from American, British and German sources, and references are given to show their origin. Some of the special topics are unusual in a text-book of aerodynamics. " Gliding," " Parachute Descent," " Seaplane Floats "—these titles indicate the varied and specialised nature of the subjects treated. An appendix gives a useful scale for reduction of tests to a standard atmosphere. A very useful book for the designer.

Guests of the Unspeakable

T. W. White. London. 12/6 net.

Lieutenant-Colonel T. W. White, the author of this book, was one of a small band of Australians and New Zealanders who were the nucleus of the Flying Corps Council in Mesopotamia in 1915. Basra has now become hardened to hearing the roar of aeroplane engines, but in those days the inhabitants looked upon aeroplanes and the efforts of Captain (as he was then) White and his men as machines and doings of the devil.

" In such a community," writes the author, " the aeroplane was a still more startling anachronism, and seemed to the Arabs as well as to the Indian troops to possess the amazing and supernatural qualities of their mythical travelling carpets and magic steeds.

" ' Will you give me a picture of the aeroplane, Sahib? ' a Mahratta subador once asked me after watching a flight; 'otherwise my relatives in India will not believe me when I tell them that I have seen men fly. They should know better,' he reflected, 'for we have read how the same things happened many thousands of years ago.' "

The machines used were Maurice Farmans and were soon doing valuable work. Two longhorns and one shorthorn formed the nucleus of the force, and within four days of White's arrival at Basra the Farmans had been assembled and were flying over the Turkish positions.

The author's career in the air was comparatively short. He arrived in Basra in April, 1915, and in November was captured by the Turks. It was by the merest chance that the author and his companion were not killed immediately, for it was with the greatest difficulty they were escorted to prison by Turkish soldiers in the face of a howling, infuriated mob of savage Arabs.

The greater part of this extraordinarily interesting book is concerned with the account of the author's captivity among the Turks. Much of it is grisly reading, much amusing, and all informative. The sidelights thrown upon the habits and customs of the Arabs and Turks, indeed, make the book far more than a bald record of captivity and hair-breadth escapes from death. It is a living narrative which makes one sometimes envious, but more often glad, that one's own war experiences were not acquired in the East.

The book contains many amusing stories and many sidelights are thrown upon famous people the author met. On his release the disreputable appearance

of the author and his companion led to many amusing incidents before they obtained fresh uniforms at Salonika.

Inquiring his way with Alan Bott to the Royal Air Force H.Q. from an R.A.F. recruit who had been celebrating, the latter inquired thickly, "You don't mean to say you're going to enlist, do you? Here, boys, come and see what's going to join the Air Force," he called to his companions. Then, shaking an unsteady finger at them paternally, he remarked, "Take my advice. Don't you join the Royal Air Force. We're a bad lot!"

For all those who have the wanderlust in their blood, the book will prove thoroughly enjoyable.

The A.B.C. of Flying

Lieutenant-Colonel W. Lockwood Marsh. J. Hamilton. 2/6 net.

Lieutenant-Colonel Lockwood Marsh wields the pen of a ready writer, and wields it, too, with knowledge. *The A.B.C. of Flying* is one of a useful A.B.C. series. It is divided into two parts, one on the aeroplane and one on the airship. As one would expect from the known sympathies of Colonel Marsh, Part II. is slightly larger than Part I., though the importance of the airship in the future of flying has still to be proved.

The A.B.C. of Flying is eminently readable, though one suspects that Colonel Marsh is not quite clear in the terms he sometimes uses when trying to explain the forces which come into play in flight. Colonel Marsh, too, labours under the disadvantage that the book is not illustrated. Diagrams would have made his explanations much easier to follow by the novice for whom the book is intended. But the book is an excellent introduction for those who wish to grasp the first principles, and from that point of view can be recommended. Part II., on airships, is particularly clear and, indeed, one of the best expositions of lighter-than-air craft which has been written for some time.

BRANCH NOTES

Leeds Branch

Hon. Secretary: T. M. Naylor, M.Sc., Assoc.M.Inst.C.E., A.M.I.M.E., A.R.Ae.S.I.

The following is a list of the lectures for the coming Session as at present arranged:—

October 16th.—Professor S. Brodetsky, M.A., Ph.D., F.R.Ae.S.
"The Aerodynamics of Wing Sections."

October 30th.—Major G. H. Scott, C.B.E., A.F.C.
"The Operating of Large Rigid Airships."

November 2nd.—General P. R. C. Groves, R.A.F. (Ret.).
"Britain's Position in World Aviation."

November 27th.—Flight-Lieutenant B. C. H. Cross, D.F.C., R.A.F.
"Some Practical Aspects of Flying Boat Developments."

February 26th, 1929.—N. S. Norway, A.F.R.Ae.S.
"The Control of Rigid Airships."

March 12th, 1929.—Major F. A. Bumpus, F.R.Ae.S.
"The Development of Torpedo-Carrying Aircraft."

A number of visits to works are also being arranged.

Yeovil Branch

Hon. Secretary: V. S. Gaunt, A.R.Ae.S.I.

The following is a summary of the annual report of the Yeovil Branch and a list of lectures which have been arranged:—

Annual Report

Progress.—During the last session thirteen lectures were held, including the open lecture by Flight-Lieutenant Webster, at which there was an attendance of members and friends totalling 480.

Special arrangements were arranged for members to visit the Bristol and Hamble air pageants.

A visit to the Bristol Engine Works was arranged and well attended.

A trial test examination paper for prospective Ground Engineers was set in March, and more recently coaching classes have been held to assist those members who are desirous of improving their positions by securing Ground Engineers' Licences.

The membership has risen during the past year from 117 to 177. The increase in membership shows that the Society is fulfilling a useful purpose, but it is felt that the number of members who actively share in promoting the Society's interests could and should be increased.

Syllabus of Lectures

During the coming winter a good programme of lectures has been arranged. In addition we intend to arrange for at least two films to be shown at the Central Cinema. The first will be shown in October, and it is a film illustrating the manufacture and test of Bristol Jupiter aero engines, including air tests in a Westland Wapiti at Yeovil. The second film will show the manufacture and test of the Napier Lion aero engines.

A visit to the Whitehead Torpedo Co.'s Works at Weymouth is being arranged to take place in the spring of 1929.

WESTLAND AIRCRAFT SOCIETY

Lecture Session, 1928-29 (First Half)

1.	5.9.28.	Mr. W. G. Gibson, A.R.Ae.S.I., "Ground Engineers' Duties."
2.	12.9.28.	Capt. F. Mayer (Bristol Aero Club), "Ground Engineers' Duties."
3.	19.9.28.	Mr. W. G. Gibson, A.R.Ae.S.I., "Ground Engineers' Duties."
4.	22.9.28.	Mr. N. Pitcher (Westland Works), "Compass Swinging."
5.	2.10.28.	Mr. T. Carey (Westland Works), "Timber."
6.	11.10.28.	*Annual General Meeting* at the Works.
7.	22.10.28.	Brig.-Gen. P. R. C. Groves, C.B., C.M.G., D.S.O., A.F.R.Ae.S., R.A.F. (Ret.), "Britain's Position in World Aviation."
8.	25.10.28.	Showing of Instructional Film, "Bristol Jupiter Engines and Westland Wapiti Aircraft," at the Central Cinema.
	26.10.28.	Ditto
	27.10.28.	Ditto
9.	2.11.28.	W. Hackett, Esq. (Accles & Pollock), "Steel Tubing Manufacture and Manipulation."
10.	7.11.28.	Major F. M. Green, O.B.E., M.Inst.C.E., F.R.Ae.S. (Armstrong Whitworth Aircraft), "Armstrong-Siddeley Aero Engines."
11.	14.11.28.	W. Harmer, Esq. (Alfred Herbert Ltd.), "Screw Threads."
12.	21.11.28.	A. J. Croft, Esq. (Vice-President), "Steel Works."
13.	30.11.28.	W. Lind-Jackson, Esq. (D. Napier & Sons), "Napier Aero Engines."
14.	5.12.28.	T. Dickinson, Esq. (Thos. Firth & Sons Ltd.), "Evolution, Care and Maintenance of Engineers' Small Tools."

Lecture Session, 1928-29 (Second Half)

15.	4.1.29.	Wing-Commander R. M. Hill, M.C., A.F.C., R.A.F., "The Cairo-Baghdad Air Mail."
16.	7.1.29.	Representative of Bristol Aero Co., "Jupiter Engines (Installation and Maintenance)."
17.	18.1.29.	F. Handley-Page, Esq. (or Mr. Russell, Handley-Page Ltd.), "The Slotted Wing."
18.	23.1.29.	Flight-Lieutenant R. Linton-Ragg, A.F.C., R.A.F., A.R.Ae.S.I. (R.A.E., Farnborough), "Experimental Flying."
19.	30.1.29.	Major P. Bishop, O.B.E. (of D.A.I. Air Ministry), "The A.I.D." (Subject to confirmation.)
20.	6.2.29.	Representative of A.D.C. Aircraft Ltd., "Cirrus Aero Engines."
21.	15.2.19.	E. G. Richardson, Esq., B.A., Ph.D., D.Sc. (University of London), "Experiments on Model Aerofoils, etc."

22.	20.2.29.	Major J. H. Ledeboer, M.B.E., B.A. (P.S.O. of M.A.E.E., Felixstowe), "Seaplane Developments (a Résumé and Forecast)."
23.	25.2.29.	Showing of an Instructional Film (D. Napier & Sons Ltd.), "The Heart of a Lion," at the Central Cinema. (Subject to confirmation.)
	26.2.29.	Ditto
	27.2.29.	Ditto
24.	9.3.29.	Visit to Works, Whitehead Torpedo Co. Ltd., at Weymouth.